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EVALUATION OF ACCESS/NAVIGATIONAL FEATURES OF A GRAPHICAL-USER INTERFACE INSTALLED ON A PORTABLE MAINTENANCE AID

THESIS

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THESIS

Presented to the
Faculty of the School of Logistics
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Preface

Portable maintenance aids (PMAs) are being developed to access and store electronic technical information on the flightline. The current prototype PMA has redundant access/ navigational features. The purpose of this research was to determine the best access/navigational features installed on the PMA.

Completion of this thesis was a major part of the AFIT experience. We were constantly told that the thesis was both a product and a process. We would like to thank several people who helped us through the long process that produced this product. We would first like to thank our advisors, Major Michael Morabito and Professor Art Munguia. Their contributions were immeasurable. We were lucky to have thesis advisors who fit our temperament and style. They were always available for suggestions and provided valuable input when we needed it; but most importantly, they left us alone when we needed it most.

We would also like to thank the folks at Armstrong Laboratory (AL) for sponsoring us and providing insight and guidance. Many thanks to two individuals at AL, Barbara Masquelier and Laurie Quill. Without the help of these two professionals, we could not have accomplished this thesis. Laurie's expert knowledge on graphical user interfaces (GUI) was instrumental in developing our experimental design and

ensuring our screens conformed to GUI standards. A special thanks to Barbara, who graciously agreed to take us under her wing, so soon after helping two 92S thesis groups. We thank her for her experience, knowledge, energy, motivation, and sense of humor.

Of course, we couldn't have completed our thesis without the help of the people who graciously consented to participate in our experiment. Thanks to our classmates, instructors and everyone who participated in our pilot study. Their help gave us valuable insight and helped us refine our experiment. We would also like to thank the maintenance technicians from the 4950th Test Wing and 907th Logistics Support Squadron at Wright-Patterson AFB, OH, who participated in our experiment. Without these folks, our thesis would only have three chapters.

The AFIT experience was certainly much more enjoyable because of the people we met while we were here. Thanks to our friends, especially the bowling and Friday Nite dinner crowd. Last, but certainly not least, is a special thanks to Lisa's husband, Steve. Steve endured endless hours of thesis--hogging the computer (he was also trying to complete a thesis) and eating all the food.

AFIT has been fun. There is no better job than going to school and getting paid for it. However, we wouldn't want to do this again, at least not anytime soon. It's been fun...The Dynamic Duo.

Lisa Carney Roger Quinto

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Abstract

Portable maintenance aids (PMAs) are being developed to access and store electronic technical information on the flightline. The prototype PMA designed by Armstrong Laboratory personnel has redundant access/navigational features. Redundancy increases software memory usage and adds unnecessary weight to the PMA. The purpose of this research was to determine the best access/navigational feature installed on the PMA. The best feature is the feature that provides the highest degree of user satisfaction. An experiment was conducted to evaluate the following features for screen and menu access and navigation, respectively: dedicated/hardware keys, programmable soft keys, and push button keys; and number keys, cursor control keys, and programmable soft keys. Modified computer screens from the prototype PMA were used on a laptop personal computer, which simulated the PMA, to evaluate each feature one-at-a-time. Twenty-eight maintenance technicians located at Wright-Patterson AFB, OH, rated and ranked each access/navigational feature. The results indicated that the best feature for screen access and navigation was the dedicated/hardware keys and the best feature for menu access and navigation was the number keys.

EVALUATION OF ACCESS/NAVIGATIONAL FEATURES OF A GRAPHICAL USER INTERFACE INSTALLED ON A PORTABLE MAINTENANCE AID

I. Introduction

This chapter introduces the general problem of the usefulness of access/navigational features of a graphical user interface (GUI) installed on a portable maintenance aid (PMA)--a lightweight, hand-held computer used on the flightline to access aircraft technical data and diagnostic aids. Although past studies have shown the usefulness of a PMA, very little has been done to evaluate the interface installed on the computer (Masquelier, 1991; Friend and Grinstead, 1992).

In this chapter, we examine the need for research, and the general issues that affect the problem. We also examine the Computer-aided Acquisition and Logistic Support (CALS) initiative. Additionally, we give a brief overview of GUIs and interactive electronic technical manuals (IETMs). Then we define the specific problem, the research objectives, the investigative questions, and the scope and limitations of the research. Lastly, we summarize the need and importance to evaluate access/navigational features of a GUI installed on a PMA, and give an overview of the remaining chapters.

As the complexity of weapon systems increases, so does the complexity of the maintenance support equipment. An example of such support equipment is the PMA. Past studies have demonstrated the usefulness of a PMA. Armstrong Laboratory (AL) Logistics Research Division, formerly known as Air Force Human Resources Laboratory, demonstrated that a PMA would be useful in a field level maintenance shop (Thomas and Clay, 1988). A later study by Jeffrey Friend and Randy Grinstead compared two different PMAs--a head mounted display device and a flat screen display device (Friend and Grinstead, 1992). Although various studies have evaluated the usefulness of PMAs, they have not evaluated the usefulness of GUIs.

Gerald Streff and Robert Gundel conducted a study comparing the advantages of access methods--joystick versus the four-cursor keys--in using the GUI installed on the PMA (Streff and Gundel, 1992). They statistically concluded that there were little differences between the effectiveness of either input device. Additionally, Michael Morris in 1990 conducted a broader study on the efficiency and effectiveness of GUIs comparing them against text and command base interfaces. He concluded that "graphical user interfaces offer significant advantages... graphical interface systems required significantly less time to learn" (Morris, 1990:93). Armstrong Laboratory personnel decided to use a GUI on the prototype PMA.

According to Barbara Masquelier, Human Factors Engineer for AL, lab personnel performed various studies with the PMA. From these studies, lab personnel gained knowledge on the user and environment which enabled them to design the PMA graphical user interface. The GUI design criteria centered around the following:

1. Limiting the amount of computer training needed.
2. Meeting user expectations.
3. Providing a consistent GUI among hardware platforms.
4. Increasing design flexibility and creating added capability. (Masquelier, 1992)

However, there still exists a need to test the usefulness of access/navigational features of the GUI before future PMAs are fielded. This has major implications because PMAs are expected to be implemented in future weapon systems (e.g., F-22 and B-2 programs).

General Issues

The Computer-aided Acquisition and Logistics Support (CALS) initiative led to the development of specifications for interactive electronic technical manuals (IETMs). The PMA software is governed by a specification on IETMs which will be discussed later in this section. To better understand the need for research, a brief overview is provided, including a discussion of CALS, GUIs, and IETMs.

CALS. The Computer-aided Acquisition and Logistic Support initiative began in 1984 to apply existing and

emerging computer technologies to the acquisition and support of weapons systems. CALS will enable DoD to:

> Automate the storage, capture, exchange and retrieval of contracting, engineering and technical information for the whole inventory of weapons systems, as well as replacement and spare parts. (Green, 1992:53)

Two benefits of CALS are to reduce the amount of paper used and derive major cost savings through increased efficiency through standards which enable data exchange. A Ticonderga-class Navy cruiser carries over 26 tons of technical data. This load would be significantly reduced if the technical data are in electronic form rather than in paper form (Green, 1992:53). According to Green's article, it is estimated that over 30 percent of the life cycle cost of weapon systems is related to documentation. The Air Force alone spent $7.5 billion in 1989 on technical information. With CALS, DOD estimates that a savings of over 40 percent of the current acquisition cost could be cut. This amounts to a $10 billion savings a year (Green, 1992:53).

The PMA eliminates the need for the maintenance technician to transport heavy and bulky paper manuals to the weapon system being repaired (Tyree, 1992:34). And for weapon systems with technical order (TO) libraries on board, such as the C-17, the paper-based manuals will be replaced with computer mass-memory cartridges used with the PMA (Masquelier, 1992). The computer presents to the technician all the technical data needed to troubleshoot and repair the

weapon system and includes the ability to interface with the weapon system and help diagnose the problem.

Rather than a page orientation (format used for paper-based technical manuals), the data are stored in an interactive database which allows the technician to see only the applicable data and gives the technician the ability to branch out in the PMA software to associated areas. For example, during the troubleshooting of the weapon system, the technician discovers that *part A* is bad. In the page-based system, the technician would have to look in another technical manual to find the part number. With the interactive system, the technician presses a key to find the part number. The concept is to integrate all the information required for flightline maintenance into a single, easy to use source for the technician (Caporlette, 1992:51). As stated earlier, the prototype PMA, developed by AL personnel, incorporates a graphical user interface.

GUIs. Graphical user interfaces are becoming more popular as demonstrated by the popularity of Macintosh® computers and the Microsoft Windows® software program for the personal computer (Morrissey, 1992:133). Possible reasons behind such growing popularity is that "the use of graphical interfaces systems has potential for increasing user satisfaction, reducing training time, and improving accuracy" (Morris, 1990:2).

A study by James Hollan and others lists important cognitive properties of GUIs:

1. They provide a physical representational system which allows users to better understand abstract relationships and make use of the brain's powerful pattern-matching ability.
2. Graphics-based systems make the depiction of models possible that are similar to the mental models or simulations people use to reason about the world.
3. Graphical interfaces better depict physical state information or causal connections and allow the user to see changes in the state of the system.
4. Graphical systems provide the potential of directly manipulable representations of systems. (Hollan and others, 1986:25-26)

Because of the cognitive properties and growing popularity of GUIs, AL personnel decided to develop a GUI instead of a text based interface for the PMA. The PMA is an example of an of interactive electronic technical manual or IETM.

IETMs. An interactive electronic technical manual (IETM) is a "package of information needed for the diagnosis and maintenance of a weapon system, optimally arranged and formatted for interactive screen presentation to the end user on an electronic display system" (Department of Navy, 1992:1). The technical information is based on the electronic form rather than the paper-based form. According to Rainey and Fuller, there are:

> Deleterious effects of page-oriented information presentation on user performance...in terms of difficulty in finding the required information, in frequently poor comprehensibility, and in the presence of technical errors which were not eliminated during the preparation and inspection procedures. (Rainey and Fuller, 1991:10)

These effects could lead to maintenance errors, increased time-to-repair, false part removals, and increased training time. According to Chelouche, problems with paper-based technical manuals (TMs) are numerous. Some of the problems with paper-based manuals are:

1. Weight and space demands for TM libraries.
2. Time required to locate data within a given manual.
3. Requirements to reference other technical manual, resulting in a mass of paper required to perform maintenance tasks.
4. Low quality updates due to reliance on manual insertion of new correction pages or pen-and-ink correction made to existing pages.
5. High investment required for training technicians.
6. Rising costs associated with maintaining TMs.
7. Low quality maintenance due to the discrepancy between the reading capability of the technician and the language and format of the manuals.
8. Lack of guidance from experienced personnel, thereby resulting in a higher rate of maintenance errors and increased down-time. (Chelouche, 1992:17)

IETMs, such as the PMA, were designed to eliminate or lessen the above problems.

Specific Problem

Armstrong Laboratory engineers used their experience and research to develop the prototype GUI; however, they never fully tested the usefulness of access/navigational features of the prototype GUI installed on the prototype PMA. This lack of testing leads to the research question: Which access/navigational features enable the user to access information from the PMA with the highest degree of user satisfaction?

For the purpose of this research the following definitions are used:

User Satisfaction. User satisfaction is a subjective rating determined by the user based on the fulfillment of the user's expectations.

Dedicated/Hardware Keys. Dedicated/Hardware keys keep the same function regardless of the current screen being displayed. Examples of dedicated keys are the *NEXT* and *CANCEL* buttons (See Figure 1).

Programmable Soft Keys. Programmable soft keys are unlabeled keys whose functions are determined by the current screen. Although these keys are hardware components, their function changes from screen to screen (See Figure 1).

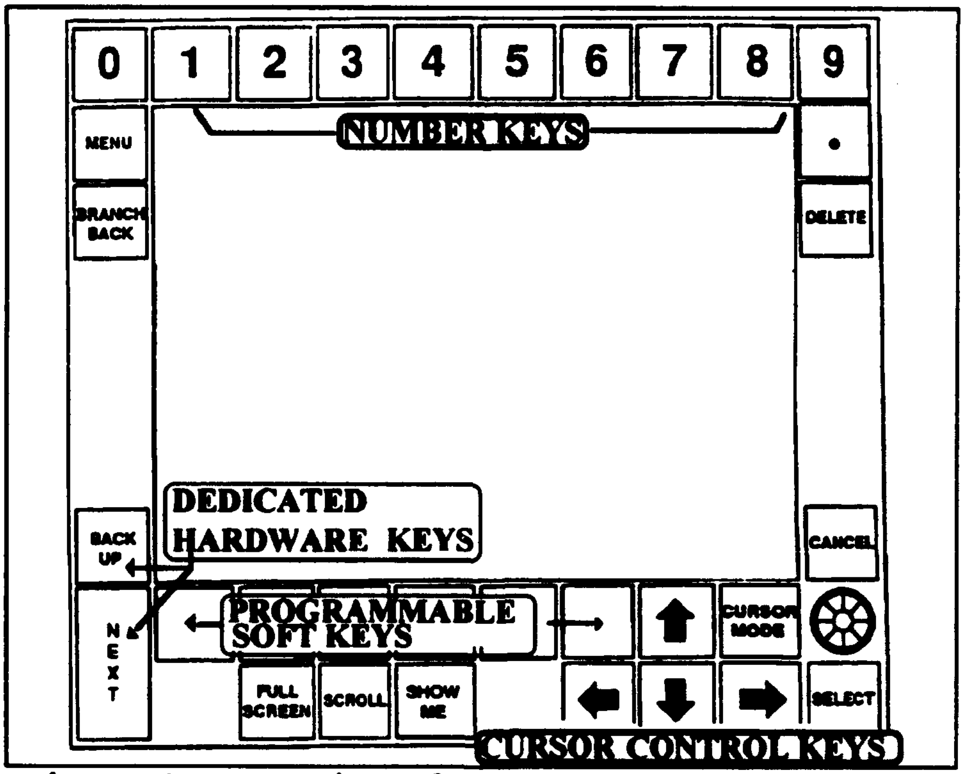


Figure 1. Location of Key Components on the PMA (Eagle Technology, 1991:3)

Push Button Keys. Push button keys are similar to programmable soft keys in that their functionality changes depending on the screen; however, the button is presented on the screen and is accessed by an on-screen move and select action, not a hardware key action.

Menu Bar. The menu bar is the area at the top of the display device screen used to access available system functions. Through the menu bar the user can also access pull-down menus or submenus.

Cursor Control Keys. Cursor control keys are the four directional arrow hardware keys used to access or navigate the screen (See Figure 1).

Number Keys. Number keys are dedicated keys that are used to input numbers or access the menu bar (See Figure 1).

Research Objectives

The objective is to determine which access/navigational features enable the user to access information from the PMA with the highest degree of user satisfaction. The experiment focuses on six access/navigational features installed on the prototype GUI. The experiment is divided into two main tasks. The first task evaluates screen access and navigation using the following three features: dedicated/hardware keys, programmable soft keys, and push button keys. The second task evaluates menu access and

navigation using the following three features: number keys, cursor control keys, and programmable soft keys.

By finding the best navigational/access features, redundant features can be eliminated, and software memory requirements reduced. Eliminating the options available on the GUI will ultimately save the DoD money and make the system easier for the technician to learn and use.

Investigative Questions

To answer the research question, the following areas are investigated:

1. What are the differences in total task completion times among the three features in each main task?

2. What are the differences in total key strokes among the three features in each main task?

3. What is the correlation between total task completion times and total key strokes?

4. What is the correlation between total task completion times and user satisfaction?

5. What is the correlation between total key strokes and user satisfaction?

6. Which access/navigational feature provides the most user satisfaction?

7. What is the statistical difference between non-experienced and experienced computer users when rating the features according to user satisfaction?

Scope and Limitations

The scope of this research was limited to the prototype GUI on the prototype PMA developed by AL personnel. The lab personnel developed the GUI using the military specification MIL-M-87268, hereby referred to as the IETM-GCSFUI, which gives guidelines for designing GUIs. The specification states:

> A common set of user-interface components and presentation conventions shall be used to provide a consistent user-interface across all presentations devices. These user-interface components and presentation conventions are common to most Graphical User Interfaces. The common interface components described in this specification shall be implemented on all of the various types of presentation systems from a large screen device to a portable small screen device. (Department of Defense, 1992:21)

The screens designed for the experiment followed the guidelines outlined in the IETM-GCSFUI. Specifically, the sections dealing with the following: common user interface components, cursor controls, menu systems, display formatting, general display format for IETMs and required navigation functions. These areas are located in sections 3.4.1 to 3.5.2 in the IETM-GCSFUI (Department of Defense, 1992:21-43).

In order to keep the experiment focused on comparing access/navigational features, we designed an experiment using screens that specifically evaluate the features being tested. The screens contained maintenance information, but were limited to simple operations to keep the focus on testing the access/navigational features and not the

technical data. Because of the modified computer screens, a personal laptop computer was used to simulate a PMA. The keys on the PMA and personal computer keyboard are not exactly the same. This dissimilarity was a limitation, but should not have adversely affected the results.

The experiment was conducted in a controlled environment inside a maintenance avionics shop. Additionally, the study was limited to Air Force maintenance personnel who were stationed locally at Wright-Patterson AFB, OH.

Summary

Portable maintenance aids help the technician maintain, diagnose, and repair malfunctions on a weapon system. Two studies have demonstrated the need for PMAs. These studies validated the usefulness of such aids in both the in-shop and flightline environment. Another study compared input devices, joystick and four-cursor keys, on the PMA. The results of this study suggested that there were no significant statistical differences between the input devices. Another study compared GUIs with text and command based interfaces, stating that GUIs decreased training time and provided a consistent interface. There is, however, a need to evaluate access/navigational features of the prototype GUI installed on the prototype PMA.

In this chapter, we discussed CALS, GUIs, and IETMs. Additionally, we defined the specific problem to be investigated: Which access/navigation features enable the user to access information from the PMA with the highest degree of user satisfaction? We also stated the investigative questions, and discussed the scope and limitations of the research.

Chapter II, Literature Review, contains background information, and further establishes the need for research. Chapter III, Methodology, describes the details of the experiment. Chapter IV, Findings and Analysis, provides the results of the experiment, more specifically, it answers the investigative questions. Chapter V, Conclusion and Recommendations, lists conclusions and recommendations for follow-on experiments. A list of acronyms used in this thesis is included in Appendix A.

II. Literature Review

Introduction

The weapon systems of the Department of Defense (DoD) are becoming increasingly complex. This complexity of design directly influences the complexity of maintenance performed on the weapon system. Interactive electronic technical data (versus paper-based technical data) are needed to maintain advanced systems, such as the B-2 and the F-22. Automation promotes speed and accuracy in updating data, and allows technicians to have the most current diagnostic and technical information at their finger tips. More importantly, the information is integrated and interactive, which results in faster accessing times, fewer false part removals, increased productivity of inexperienced technicians, and reduced maintenance downtimes.

One way for the technician to access this information is through a portable maintenance aid (PMA), a computer that is easily transported to the flightline. The prototype PMA incorporates a graphical user interface (GUI) versus a text/command-based interface. The Armstrong Laboratory tested the feasibility of a PMA, but never fully tested the usefulness of certain access/navigational features of the prototype GUI. Our research evaluates certain access/navigational features of the GUI to determine the

features with the highest degree of user satisfaction. The purpose of our experiment is to identify which access/navigational feature (specified in MIL-M-87268) work best given the maintenance data and environment. This effort is to ensure that access/navigational features of prototype maintenance PMA GUIs are suitable for future and emerging programs such as the B-2 and F-22 programs.

The purpose of this chapter is to provide the framework for our research on testing certain access/navigational features of the prototype GUI. First, we review the evolution of automated technical data and diagnostic systems, beginning with the Computer-aided Acquisition and Logistic Support (CALS), and automated technical orders. We then discuss the Computer-based Maintenance Aids System (CMAS) and the Integrated Maintenance Information System (IMIS). We conclude with past research on PMAs and GUIs, and establish the need for research.

Computer-aided Acquisition and Logistic Support (CALS)

CALS resulted from the DoD effort to automate and streamline the purchase, maintenance, modification, and documentation of activities conducted to support a weapon system. The first objective of CALS is to automate the delivery of technical information, including engineering drawings and technical/logistics support data, from the contractors to the users. The second objective of CALS is

to create a unified data base for information sharing among DoD and industry (O'Neal, 1989:42).

A DoD task force was formed in 1984 to study the feasibility of a DoD-wide computer-aided logistic support system. The task force was composed of senior industry and government personnel with the official charter to develop a strategy and recommend a master plan for CALS implementation. The task force cited the following logistics problems that CALS could alleviate:

1. Incomplete/illegible engineering drawings.
2. Inaccurate/incomplete re-procurement documentation.
3. Outdated technical data.
4. Expensive/enormous paper-based technical information.
5. Inadequately documented configuration data. (Correale, 1987:192)

In August 1988 the Deputy Secretary of Defense William Taft issued a memorandum instructing program managers to include CALS standards in new weapon system acquisitions (Taft, 1988:1). This memo was important to the CALS program because it gave CALS renewed interest at the highest levels.

Two lead programs have driven the CALS effort: the Navy's Engineering Data Management Information and Control System (EDMICS), awarded to PRC Inc in 1989, and the Army's program, Army CALS (ACALS), awarded to Computer Science Corp in Fall 1991 (Jenks, 1992:28). In 1991, ACALS was renamed J-CALS after combining with the Air Force's CALS program--Joint Uniformed Service and Technical Information System (JUSTIS). In 1992, much of the momentum of CALS shifted from EDMICS to J-CALS (Jenks, 1992:28).

EDMICS is concerned with converting engineering drawings from huge stacks of paper to electronic digits. J-CALS, however, is more of a day-one forward system designed to support the weapon system throughout its life cycle, including all associated paperwork. As stated earlier, the first objective of CALS is to automate and standardize the delivery of technical information. Accurate technical orders are needed to maintain and support today's weapon systems.

Technical Orders

Technical Orders (TOs) are used by Air Force technicians to help maintain and support weapon systems. The current paper-based system is extremely bulky. According to Major McClain of the F-16 program office, the F-16 fighter aircraft requires 1,963 TOs to maintain and operate it (McClain, 1993). It is estimated that one B-1 bomber alone requires over 1.5 million technical drawings to maintain and support it (Jenks, 1992:37). Not only is the current system paper intensive, but keeping the manuals updated involves many manhours.

If the technical data change, manuals have to be updated using the original paper source. The Navy requires approximately 1,000 sailor-years annually just to keep its manuals current (Nordwall, 1990:66). According to Kerr, at any one time, 10 percent of the information in TOs is

outdated (Kerr, 1988:81). Outdated technical information leads to incorrect maintenance actions, which can result in loss of life, safety problems, or damage to expensive parts. Technicians use computers not only to access automated technical information, but also to access diagnostic aids used to troubleshoot weapon system malfunctions.

Computer-based Maintenance Aids System (CMAS)

The Computer-based Maintenance Aids System (CMAS) development program introduced the use of computers to present maintenance procedures for intermediate-level equipment. According to Donald Thomas and Jeffrey Clay, the initial attempt began in 1978 to develop an automated technical data presentation system (ATDPS) for use in intermediate level maintenance shops (off-equipment maintenance). The initial focus of this effort was on the development of human factors and technical data requirements. However, a CMAS prototype was never built because of an operational requirement requiring the computer to be deployable (Thomas and Clay, 1988:4).

Thomas and Clay state that in 1982, AL made a second attempt to develop an ATDPS prototype for intermediate level maintenance. CMAS-I, as it was called, used commercially available hardware and adapted the Navy Technical Information Presentation System for its use. CMAS-I was installed in an intermediate-level avionics maintenance shop

at Offutt AFB, Nebraska, for evaluation. However, CMAS-I failed to validate its usefulness because the program lacked acceptance from the users, primarily due to slow response times and ineffective man-machine interface techniques (Thomas and Clay, 1988:5).

A follow-up to CMAS-I, called CMAS-II, used a Grid Compass Model 1139 microcomputer for its hardware and incorporated many of the design features in CMAS-I. However, priority was placed to improve the response times and interactions between man and machine. CMAS II was installed at Grissom AFB, Indiana, in June 1988. After gaining acceptance from the users, and demonstrating the viability of computer-based maintenance aids, the CMAS-II was tested again by the Navy. Following these two successful tests, specifications were developed for automated technical data systems (hardware) and for technical data presentation (software) (Thomas and Clay, 1988:6). Although the CMAS project ended, work based on the CMAS results continues under the Integrated Maintenance Information System program.

Integrated Maintenance Information System (IMIS)

The Armstrong Laboratory has been testing and developing the Integrated Maintenance Information System (IMIS) since the termination of CMAS. IMIS was developed to access and integrate maintenance information from multiple

sources and present the information to technicians through a single integrated source. On the flightline, the single source is the hand-held computer, the PMA. IMIS was developed in an attempt to consolidate other maintenance computer-based information systems (Department of the Air Force, 1987:1). Current computer-based information systems include the Comprehensive Engine Management System (CEMS-IV), and the Core Automated Maintenance System (CAMS). One benefit of the IMIS is that technicians will only have to learn one system but will have information available from many different logistic databases.

IMIS is a comprehensive maintenance system that links the flightline with the maintenance information workstation (MIW) (See Figure 2).

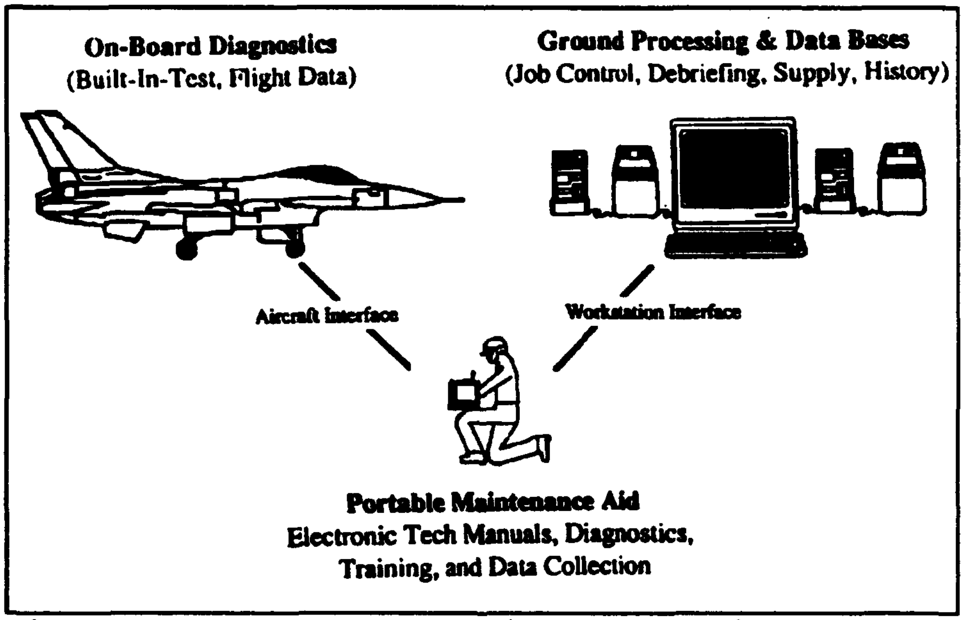


Figure 2. IMIS: Integrating Information from Aircraft to the PMA and the MIW (Masquelier, 1992)

IMIS is divided into hardware and software subsystems. The following section discusses the subsystems in more detail (Department of the Air Force, 1987:45-47).

Portable Maintenance Aid (PMA). The PMA is a compact, lightweight, battery-powered, portable computer, rugged enough for flightline use. The PMA displays technical order information, which is stored on removable memory cartridges. Besides displaying technical information, the PMA has diagnostic aids installed to help the technician troubleshoot difficult maintenance problems.

Maintenance Information Workstation (MIW). The MIW is an in-shop workstation with an interface computer. The MIW can interface with the PMA and other maintenance information systems, like CAMS and CEMS-IV.

Integration Software. Integration software allows the technician to access all the information through one device. Before IMIS, technicians had to learn several different maintenance information systems to accomplish the task.

Applications Software. Applications software is a comprehensive database used to troubleshoot and maintain the weapon system. This database incorporates various sources of information in one place.

As the IMIS concept evolved, AL personnel designed several prototype PMAs which incorporated the use of GUIs.

Portable Maintenance Aids

Accurate, up-to-date information is needed to maintain today's complex weapon systems. How the technicians receive this information has been the focus of past research. In 1991, Barbara Masquelier researched the feasibility of a head mounted display device (HMDD) because a flat screen computer has limitations. A flat screen computer does not physically fit in all compartments of an aircraft, prohibiting technicians from accessing necessary information at all times (Thomas and Clay, 1990). To help alleviate these limitations, Masquelier compared the monocular HMDD to a portable laptop computer, using avionics technicians in an in-shop repair environment. Her research objective was to determine if a performance difference existed on the basis of the display device (HMDD vs laptop computer). She found no statistically significant evidence of one device improving performance over the other (Masquelier, 1991:67).

A follow-on study to Masquelier's research was conducted in 1992 by Jeffrey Friend and Randy Grinstead. They expanded Masquelier's research to a flightline environment. They conducted two maintenance tasks to determine the effects of the display type (HMDD or PMA) on the technician performance. Their study concluded, "...that there are some tasks, specifically complex procedural tasks and inspection tasks, that may benefit from the use of an HMDD" (Friend and Grinstead, 1992:75).

Gerald Streff and Robert Gundel also conducted research in 1992 on the PMA. Their research focused on the comparison of four-cursor buttons and a joystick to access computerized technical information. They concluded: "Data collected during this experiment indicated that there are no statistical differences in access times using either the joystick device or the four-cursor key configuration" (Streff and Gundel, 1992:65). AL personnel tested different types of PMAs and hardware input devices, but never tested certain access/navigational features of the prototype GUI.

Graphical User Interfaces

According to Ralph Sabene, the GUI has become the standard operating environment for most software programs in the last ten years (Sabene, 1992:2). The Xerox Palo Alto Research Center introduced the first GUI in the 1970s (Baran and Hayes, 1989:250).

Apple Computer introduced the next GUI with the Lisa® computer in 1983. However, it wasn't until the introduction of the Macintosh® Computer in 1984 that the GUI became commercially successful. According to Sabene, "most people today credit the Apple Macintosh® as starting the 'GUI revolution'" (Sabene, 1992:2). Later, Microsoft Corporation contributed to the GUI popularity by introducing a GUI, Windows®, for IBM compatible computers (Sabene, 1992:2).

However, Windows® and Macintosh® are not the only GUIs available. The popularity of GUIs is widespread, crossing many hardware and software platforms. Table 1 shows the available hardware/software platforms for GUIs.

TABLE 1

AVAILABLE HARDWARE/SOFTWARE PLATFORMS
USING GRAPHICAL USER INTERFACES

Software/Hardware Platforms	GUIs
Apple	Macintosh
Microsoft	Windows 3.1
IBM	OS/2 2.0
Digital Equipment Corporation	DECwindows
Open Software Foundation	Motif
Santa Cruz Operation (SCO)	Open Desktop
Commodore Amiga	Intuition
NeXT Computer	NeXT Step
Digital Research	GEM
Sun Microsystems	Open Look
Hewlett-Packard with Microsoft	Common X Interface
Hewlett-Packard	NewWave

(Adapted from Baran and Hayes, 1989)

GUI Components. GUIs differ from text/command based interfaces by their manipulation of graphics or pictorial representations to achieve a command or function rather than through a command that must be typed. Baran and Hayes identified a list of parts that are usually part of GUIs.

They are listed below with a short description:

1. A pointing device, usually a mouse or cursor used to select items in the interface. Other pointing devices include light pens and joysticks.
2. Through use of a pointing device, menus can pop up when a menu item is selected.
3. Windows that graphically display what the computer is doing.
4. Icons that represent files, directories, etc.
5. Dialogue boxes, buttons, sliders, check boxes, and a plethora of other graphical widgets that let you tell the computer what to do and how to do it. (Baran and Hayes, 1989:250)

A GUI does not have to include all these features in order to be considered a GUI; however, most GUIs include many of these features.

Graphical User Interface Design. In order to design a GUI, the designer can follow guidelines established by many researchers in the field of interface design and human-computer interface design. A search of the past research shows that Sidney Smith and Jane Mosier identified 944 guidelines for designing user interface software (Smith and Mosier, 1986). The guidelines range from the general to specific details.

In contrast, Ben Schneiderman identifies eight general guidelines which "provide a good checklist for ensuring that a design has at least included consideration of issues commonly applicable to user interfaces" (Peabody, 1991:7). Schneiderman's eight principles are listed in Table 2.

TABLE 2

SCHNEIDERMAN'S EIGHT USER-INTERFACE PRINCIPLES

1.	Strive for consistency
2.	Enable frequent users to use shortcuts
3.	Offer informative feedback
4.	Design dialogues to yield closure
5.	Offer simple error handling
6.	Permit easy reversal of actions
7.	Support internal locus of control
8.	Reduce short-term memory load

(Adapted from Schneiderman, 1987)

Schneiderman's first principle, consistency, is important because it allows the user to focus on the task rather than concentrating on how to maneuver around the interface. Under the IMIS concept, maintainers will use several different computers to accomplish their job. Having a consistent interface on both the PMA and the in-shop workstation decreases training time because only one interface has to be learned. When designing a good interface, the designer should encompass as many as the Schneiderman's eight principles as possible.

The Need for Research

According to Barbara Masquelier, Human Factors Engineer, AL personnel performed field evaluations using the PMA and the prototype GUI, but never specifically compared

access/navigational features of the prototype GUI. Laboratory personnel feel it is important to evaluate access/navigational features of the GUI as outlined in the military specification (MIL-M-87268) governing GUIs. Through formal evaluation of GUI features, assessments can be made as to which access/navigational features accommodate good user interface design for maintenance data and environments. Our research evaluates certain access/navigational features of the GUI to determine which features provide the highest degree of user satisfaction.

Summary

In this chapter, we discussed the evolution of the portable maintenance aid and the graphical user interface. We discussed the Computer-aided Acquisition and Logistic Support (CALS) initiative, automated technical orders, and the first test of a PMA--Computer-based Maintenance Aids System (CMAS). We reviewed the Integrated Maintenance Information System (IMIS) program and past research on PMAs. We concluded with past research on GUIs, and established the need for research. Chapter 3, Methodology, outlines the details of the experiment, including the experimental design and method of analysis.

III. Methodology

Introduction

As stated in Chapter I, portable maintenance aids (PMAs) are needed to support and maintain weapon systems. A graphical user interface (GUI) is installed on the PMA; the current prototype GUI, the AL demonstration device, has redundant access/navigational features. The purpose of this research is to determine the "best" access/navigational feature to use on future PMAs and to evaluate those features specified in the IETM-GCSI. Best feature is defined as the feature providing the highest mean value for overall user satisfaction. To find the best feature, we conducted an experiment evaluating six access/navigational features. First we discuss the experimental design. Then we address the elements of the experiment, including subjects, tasks, training, and hardware/software. Next, we discuss data collection and review the investigative questions. We then address the method of analysis and conclude with a brief summary of the chapter.

Experimental Design

Researchers use experiments to gather information to test hypotheses. Experiments have many advantages over other methods in collecting data. According to Emory and

Cooper, "the foremost advantage is the researcher's ability to manipulate the independent variables" (Emory and Cooper, 1991:418). This allows the researcher to determine if changes in the dependent variable are a result of changes in the independent variable.

Another advantage of experiments is that the researcher has greater control over contamination from extraneous variables. This helps the researcher "isolate experimental variables and evaluate their impact over time" (Emory and Cooper, 1991:418). Additionally, experiments lead to "an average effect of the independent variable across people, situations, and times" because experiments can be repeated or replicated with different subject groups and conditions (Emory and Cooper, 1991:418).

However, the artificiality of the laboratory is one of the biggest disadvantages of experiments (Emory and Cooper, 1991:418). Subjects may react differently under experimental settings than they would under normal conditions. Regardless, experiments are still one of the best methods in determining changes in dependent variables caused by changes in the independent variable.

This research incorporates a blocking factor for grouping people with and without computer experience. Randomized block experimental designs are effective when the researchers are interested in learning if there are differences in results among various groups of subjects.

There are many elements of designed experiments. McClave and Benson provide the following definitions of the elements of designed experiments:

1. Response/Dependent Variable: Variable of interest.
2. Factors/Independent Variables: Variables whose effect on the response is of interest.
3. Levels of Independent Variables: Values of the factors utilized.
4. Treatments: Factor-level combinations utilized. (McClave and Benson, 1991:860-861)

The response of interest in this experiment is the user satisfaction level for the different access/navigational features (factors) used for the two main tasks. The levels for Task 1 are dedicated/hardware keys, programmable soft keys, and push buttons keys. The levels for Task 2 are number keys, cursor keys, and programmable soft keys. The treatments are the order in which the access/navigational features are tested.

Subjects

Minimum sample size was determined by using a formula from Diamond (Diamond, 1981:27-33). According to Diamond, "The correct sample size assures the experimenter that the risks of error will be equal to or less than α and β when the experiment is completed (Diamond, 1981:33). The formula for computing sample size N is:

$$\underline{N = 2(U_\alpha + U_\beta)^2 \ \sigma^2/\delta^2} \qquad (1)$$

where U_α and U_β are the <u>normal distribution numbers for the alpha and beta risks</u>, σ^2 (sigma-squared) is the <u>variance</u> and δ (delta) is the <u>engineering factor</u>. The alpha risk is the probability of rejecting the null hypothesis when it is true. The beta risk is the probability of failing to reject the null hypothesis when it is false. The larger the sample size N, the smaller the risk of an alpha or beta error.

This formula calculated the minimum sample size by using alpha and beta errors equal to the overall significance level (0.05 for this experiment) and a delta equal to one standard deviation. Using Table 1 from Diamond's book, $U_\alpha = 1.960$ and $U_\beta = 1.282$. Using these values and equation 1, the minimum sample size, N, is 21 (Diamond, 1981:28-30,325). A total of 28 maintenance technicians from the Communication/ Navigation, Guidance Control, and Electro-Environmental shops within the 4950th Test Wing located at Wright-Patterson AFB, OH and avionics technicians from the 907th Logistics Support Squadron, also located at Wright-Patterson AFB, participated in this experiment. The 4950th Test Wing and Reserve personnel were selected mainly because of their availability, but also because they provided a good cross-sectional sample of the population of all Air Force technicians.

These technicians were randomly divided into two groups. The first group accomplished Task 1 first and then Task 2. The second group accomplished Task 2 first then Task 1. This minimized recency effects. Each group had

non-experienced and experienced computer users. We used background surveys (See Appendix B) to gather background information on the technicians. We distributed the survey to the various shops. The surveys yielded 13 non-experienced and 15 experienced computer users for a total of 28 subjects. A non-experienced computer user is operationally defined as having less than three years computer experience, and an experienced computer user is defined as having over three years computer experience.

For the purpose our research, maintenance skill-level is not a factor. Since we are evaluating a GUI access/ navigational feature, maintenance skill-level should not impact the experiment. The computer screens, however, contain maintenance information from the F/A-18 technical manuals. This information is not difficult to understand and should not influence the test. We decided to design the screens with maintenance information because the portable maintenance aid (PMA) is slated for the maintenance complex. The maintenance information on the screens is generic, and is mainly there to provide a realistic environment for the experiment.

Tasks

To evaluate GUI access/navigational features, we divided our experiment into two main tasks: Screen

Access/Navigation and Menu Access/Navigation. Each main task evaluates three access/navigational features:

TASK 1: Screen Access/Navigation

1a. Dedicated/Hardware Keys

1b. Programmable Soft Keys

1c. Push Button Keys

TASK 2: Menu Access/Navigation

2a. Number Keys

2b. Cursor Keys

2c. Programmable Soft Keys

Table 3 summarizes the experiment.

TABLE 3

GROUP AND TASK ORDER ASSIGNMENT

GROUP	Subjects	Task Order
I	14	Screen Access/Navigation Menu Access/Navigation
II	14	Menu Access/Navigation Screen Access/Navigation

Group I had 7 non-experienced and 7 experienced and Group II had 6 non-experienced and 8 experienced. Each main task consists of three subtasks, resulting in six different combinations for subtask assignment order. The subjects were randomly assigned to one of the six subtask combinations in each main task to ensure that each subtask combination was used by an equal number of subjects to minimize bias results due to recency factors. For example,

Subject 1 would perform the task in the order 1a, 1b, 1c; whereas Subject 2 would perform the task in the order of 1b, 1a, 1c etc.

The subjects were required to access information and navigate their way around the screen using one access/ navigational feature until all three subtasks were completed.

The tasks used in this experiment were designed by the researchers to test, one-at-a-time, an access/navigational feature. To accomplish this, we designed each screen so all three access/navigational feature could be used. However, depending on the subtask, only one access/navigation feature was operational--the other two features were locked out. This ensures that only the feature being tested was used.

A pilot test was conducted using 11 students and instructors from the Air Force Institute of Technology stationed at Wright-Patterson AFB, OH. The purpose of the pilot study was to refine the experiment. The variability of the results from the pilot test was used to verify the sample size. The standard deviations were small enough to yield significant differences among the means, therefore a sample size of 21 or greater was sufficient.

Training

Prior to each subtask, the subject was shown the relevant keys needed for that subtask (See Appendices C, D).

Instructions for all tasks were provided on the screens, eliminating the need for paper instructions. Instructions were also given to concentrate on the access/navigational feature and not the maintenance information presented on the screens.

Hardware and Software

The hardware used for this experiment was a Compaq Contura 386SL laptop running under DOS 6.0®. The laptop was used to simulate a PMA because of its portability, weight, and small screen size. The laptop uses a 25MHz Intel chip, with a 84Mb hard drive, 4Mb of RAM and a monochrome LCD screen. During the experiment, the laptop used AC power with all power management controls turned off. Using AC power instead of battery power allowed the chip to run 100 percent of the time, producing more consistent results.

The screens used in this experiment were programmed using Visual Basic™ 2.0 for Windows. Visual Basic 2.0 for Windows is an object-oriented programming language that incorporates many of the graphical user interface features tested in this experiment. The program was compiled into an executable file and run under Windows 3.1.

Data Collection

For the purpose of our research, both quantitative and qualitative information were collected. The quantitative

information was collected through the computer. A program was written by the researchers to track total task completion times and total key stroke counts for each subtask. Both measures began on the first key stroke on the first screen for each subtask, and ended on the last screen (See Appendices E and F).

Additionally, we were able to replay any subject's task on the screen because the data being collected were kept on file in the computer. This allowed us to replicate the subject's task and more closely examine the progress and timing of each keystroke.

The qualitative information was collected by surveying the subjects after each subtask using a questionnaire (See Appendices C and D). The questionnaires combined close-ended questions, using a 5-point Likert scale, and open-ended questions. After each main task, the subjects were asked both closed and open-ended questions about all three subtask features. Additionally, the subjects were asked to rank order the access/navigational features to determine their preference.

Investigative Questions

The data collected were used to answer the following investigative questions:

1. What are the differences in total task completion times among the three features in each main task?

2. What are the differences in total key strokes among the three features in each main task?

3. What is the correlation between total task completion times and total key strokes?

4. What is the correlation between total task completion times and user satisfaction?

5. What is the correlation between total key strokes and user satisfaction?

6. Which access/navigational feature provides the most user satisfaction?

7. What is the statistical difference between non-experienced and experienced computer users when rating the features according to user satisfaction?

The answers to the investigative questions will determine which access/navigational feature provides the highest degree of user satisfaction.

Method of Analysis

Answers to the closed-ended questions were converted to a number from one to five based on the subject's response on the 5-point Likert scale. The method used to analyze the data was a one-way Analysis of Variance (ANOVA). We used the computer program STATISTIX® Version 4.0, Analytical Software, to create a ANOVA summary table to determine the variability attributable to the treatments, blocks and

errors. The ANOVA summary table tested the null hypothesis that there are no differences among the means for the three access/navigational features. The Bonferroni Pairwise Comparison of Means was used to determine homogeneous groups among the feature. Additionally, computer experience was blocked to determine if computer experience affects the means. An overall F-test with a 0.05 significance level was used to test for statistical significance.

Summary

In this chapter, we defined our methodology. A randomized block experimental design was used to determine the best access/navigational feature. The experiment was divided into two main tasks. These tasks involved accessing information and navigating through several computer screens. Personnel, located at Wright-Patterson AFB, were the test subjects for this experiment. They were trained prior to each subtask and were asked questions relating to their satisfaction with each access/navigational feature. Access times and total keystrokes were collected by the computer program. This information, combined with the questionnaire results, was used to answer the investigative questions. An analysis of variances (ANOVA), with a significance level of 0.05, was used to analyze the data. The results of the experiment are presented in Chapter IV, Findings and Analysis.

IV. Findings and Analysis

Introduction

As stated in Chapter 3, this experiment used quantitative and qualitative measurements. The quantitative measurements included questionnaire results, total task completion times, and key strokes. The results from the questionnaire were converted to numerical ratings of 1-5 (1 = strongly agree, 2 = agree, 3 = undecided, 4 = disagree, and 5 = strongly disagree) and analyzed using an Analysis of Variance and Bonferroni Pairwise Comparison of Means. These data are discussed in the Quantitative Analysis Section. The mean values for the total task completion time and key stroke measurements for each tested feature were collected and analyzed using the Bonferroni comparison. These data are discussed in the Investigative Question Section.

The qualitative measurements were collected using open-ended questions on the questionnaire. The data collected from these questions were used to provide insight and further substantiate the quantitative results. These data are discussed in the Qualitative Analysis Section. This chapter is divided into three main sections. The first section discusses the quantitative analysis for each main task, Task 1 and Task 2. The second section answers the seven investigative questions posed in Chapter 1 and 3. The third section addresses the qualitative analysis,

summarizing the open-ended questions. This chapter concludes with a summary of our findings and analysis.

Quantitative Analysis

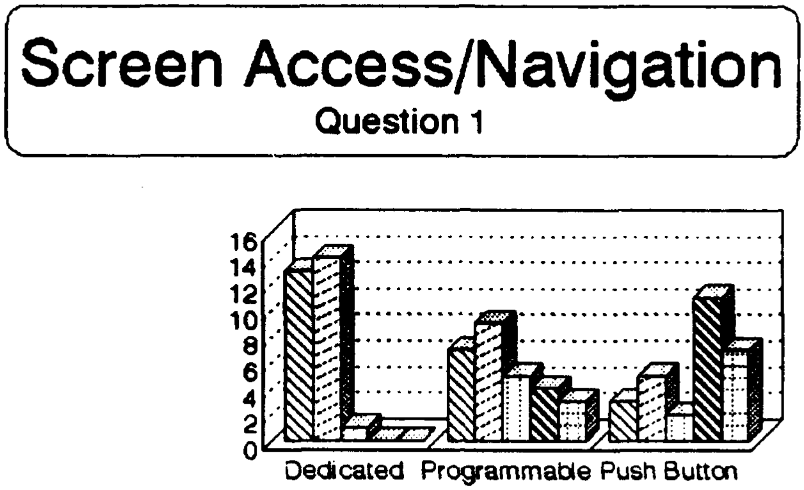
This section analyzes the quantitative measurements (numerical responses to questionnaire) collected in the experiment. The analysis is presented in two main sections: Task 1 and Task 2.

Task 1: Screen Access and Navigation. The features in this task included: dedicated/hardware keys, programmable soft keys, and push button keys. Each question from the questionnaire is discussed separately.

Question 1. *The feature provided a high degree of user satisfaction when moving from one screen to the next.* Out of 28 responses, the following rated the feature strongly agree or agree: 27 for the dedicated/hardware keys, 16 for the programmable soft keys, and only 8 for the push button keys. Equally important is the number of people who rated the feature strongly disagree and disagree. Eighteen people rated the push button keys this way. These results indicate that people prefer dedicated/hardware keys and do not prefer push button keys when moving from one screen to the next (See Figure 3).

To further analyze the results, we performed an analysis of variances (ANOVA) to determine if there were

significant differences among the means for the three features. The ANOVA results are summarized in Table 4.



		Dedicated	Programmable	Push Button
1: Strongly Agree		13	7	3
2: Agree		14	9	5
3: Undecided		1	5	2
4: Disagree		0	4	11
5: Strongly Disagree		0	3	7

Figure 3. Histogram Depicting Results for Task 1, Question 1

TABLE 4

RESULTS OF THE ANOVA FOR TASK 1, QUESTION 1

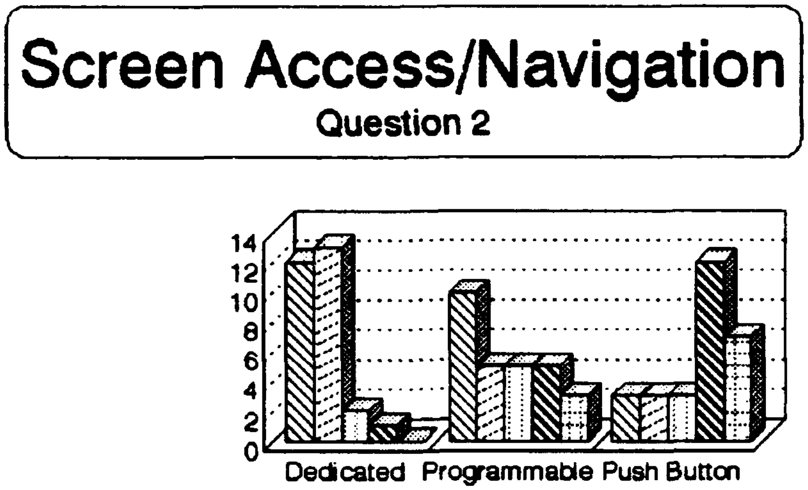
Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	54.0238	27.0119	21.13	0.0000	
Within	81	102.678	1.26763			
Total	83	156.702				
Feature		**Mean**	**Std Dev**	**Homogeneous Groups**		
Ded/Hardware		1.5714	0.5727	I		
Programmable		2.5714	1.2889		I	
Push Button		3.5357	1.3466			I

To determine if there is a significant difference among the means, we tested the null hypothesis that no significant differences exist. If the p-value is less than the level of significance, then the null hypothesis is rejected and the alternative hypothesis, there are significant differences among the means, is accepted. Since the above p-value of 0.0000 is less than the level of significance of 0.05, the overall F-test shows that there are significant differences among the means. Table 4 also summarizes the mean and standard deviation for each feature. The overall F-test indicates that there are "some contrast that's significant, but does not guarantee than any pairwise comparison is particularly important" (Statistix User Manual, 1992: 203).

To determine if there are any significant differences among the pairwise comparisons, we compared the mean values by using the Bonferroni Pairwise Comparison of Means. Bonferroni results in an experimentwise error rate of less than α (0.05). Bonferroni is a conservative test for pairwise comparisons. Less conservative comparison methods may yield results showing differences, but they result in experimentwise errors greater than α (Statistix User Manual, 1992: 203). This comparison shows homogeneous groups, represented by the *I* in the same column. If the groups are not homogeneous, the *I*s appear in separate columns. According to the results shown in Table 4, all three means are significantly different from one another--no two features have *I*s in the same column.

Since the mean values are all significantly different and the mean value for dedicated/hardware keys is 1.5714 (corresponding to agree/strongly agree), dedicated/hardware keys provided the most user satisfaction when moving from one screen to the next.

Question 2. *The feature provided a high degree of user satisfaction when navigating up and down the screen.* Out of 28 responses, the following rated the feature strongly agree or agree: 25 for dedicated/hardware keys, 15 for programmable soft keys, and 6 for push button keys. Nineteen people rated push button keys strongly disagree or disagree. These results, as shown in Figure 4, indicate that people prefer dedicated/hardware keys and do not prefer push button keys when navigating up and down the screen. The ANOVA results are summarized in Table 5.



	Dedicated	Programmable	Push Button
1: Strongly Agree	12	10	3
2: Agree	13	5	3
3: Undecided	2	5	3
4: Disagree	1	5	12
5: Strongly Disagree	0	3	7

Figure 4. Histogram Depicting Results for Task 1, Question 2

TABLE 5

RESULTS OF THE ANOVA FOR TASK 1, QUESTION 2

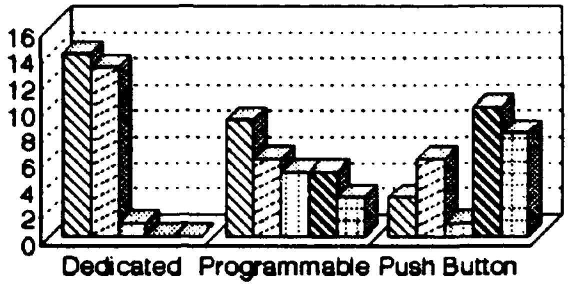
Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	52.4523	26.2261	18.78	0.0000	
Within	81	113.107	1.39638			
Total	83	165.559				
Feature		**Mean**	**Std Dev**	**Homogeneous Groups**		
Ded/Hardware		1.7142	0.7629	I		
Programmable		2.5357	1.4005		I	
Push Button		3.428	1.1816			I

Since the above p-value of 0.0000 is less than the level of significance of 0.05, the overall F-test shows that there are significant differences among the means. The Bonferroni Comparison of Means shows that all three means are significantly different from one another.

Since the mean values are all significantly different and the mean value showing the highest degree of user satisfaction is 1.7142 for the dedicated/hardware keys, the dedicated/hardware keys provided the most user satisfaction when navigating up and down the screen.

Question 3. *The feature provided a high degree of user satisfaction when moving from one line to the next, after inputting text.* Out of 28 responses, the following rated the feature strongly agree or agree: 27 for dedicated/hardware keys, 15 for programmable soft keys, and 9 for push button keys. Eighteen people rated push button keys strongly disagree or disagree. These results, as shown in Figure 5, indicate that people prefer dedicated/hardware keys and do not prefer push button keys when moving from one line to the next, after inputting text. The ANOVA results are summarized in Table 6.

Screen Access/Navigation
Question 3



	Dedicated	Programmable	Push Button
1: Strongly Agree	14	9	3
2: Agree	13	6	6
3: Undecided	1	5	1
4: Disagree	0	5	10
5: Strongly Disagree	0	3	8

Figure 5. Histogram Depicting Results for Task 1, Question 3

TABLE 6

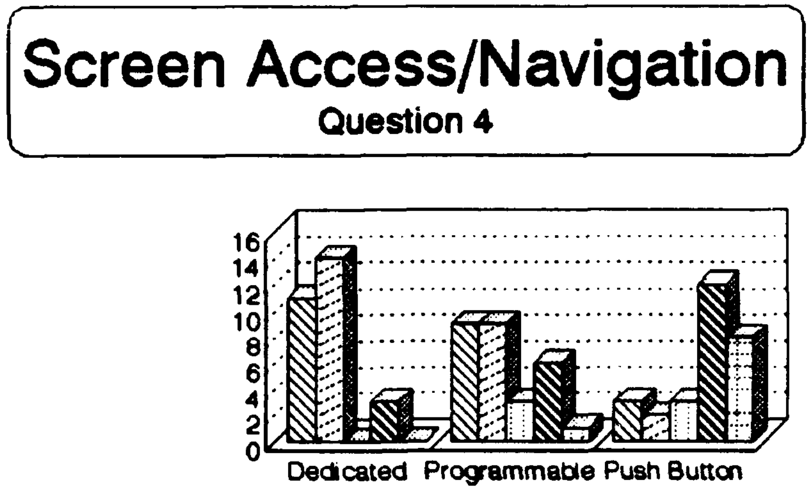
RESULTS OF THE ANOVA FOR TASK 1, QUESTION 3

Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	60.0952	30.0476	22.00	0.0000	
Within	81	110.607	1.36552			
Total	83	170.702				
Feature		**Mean**	**Std Dev**	**Homogeneous Groups**		
Ded/Hardware		1.5357	0.5762	I		
Programmable		2.5357	1.4005		I	
Push Button		3.6071	1.3427			I

Since the above p-value of 0.0000 is less than the level of significance of 0.05, the overall F-test shows that there are significant differences among the means. The Bonferroni Comparison of Means shows that all three means are significantly different from one another.

Since the mean values are all significantly different and the mean value showing the highest degree of user satisfaction is 1.5357 for the dedicated/hardware keys, the dedicated/hardware keys provide the most user satisfaction when moving from one line to the next, after inputting text.

Question 4. *Few accessing and selection errors were made when using this feature.* Out of 28 responses, the following rated the feature strongly agree or agree: 25 for dedicated/hardware keys, 18 for programmable soft keys, and 6 for push button keys. Eighteen people rated push button keys strongly disagree or disagree. These results, as shown in Figure 6, indicate that people made the fewest access and selection errors with the dedicated/hardware keys and the most errors with the push button keys. The ANOVA results are summarized in Table 7.



	Dedicated	Programmable	Push Button
1: Strongly Agree	11	9	3
2: Agree	14	9	2
3: Undecided	0	3	3
4: Disagree	3	6	12
5: Strongly Disagree	0	1	8

Figure 6. Histogram Depicting Results for Task 1, Question 4

TABLE 7

RESULTS OF THE ANOVA FOR TASK 1, QUESTION 4

Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	45.0238	22.5119	17.98	0.0000	
Within	81	101.392	1.25176			
Total	83	146.416				
Feature		**Mean**	**Std Dev**	**Homogeneous Groups**		
Ded/Hardware		1.8214	0.9048	I		
Programmable		2.3571	1.2236	I		
Push Button		3.5714	1.1996		I	

Since the above p-value of 0.0000 is less than the level of significance of 0.05, the overall F-test shows that there are significant differences among the means. The Bonferroni Comparison of Means shows that dedicated/hardware and programmable soft keys are not significantly different; however, both are significantly different from push button keys.

Since dedicated/hardware and programmable soft keys have the lowest mean value and are significantly different from push button keys, both dedicated/hardware and programmable soft keys provided the fewest access and selection errors.

Question 5. *Overall, the feature provided a high degree of user satisfaction when accessing and navigating the screens.* Out of 28 responses, the following rated the feature strongly agree or agree: 25 for dedicated/hardware keys, 16 for programmable soft keys, and 5 for push button keys. Twenty people rated push button keys strongly disagree or disagree. These results, as shown in Figure 7, indicate that people overall prefer dedicated/hardware keys and do not prefer push button keys when accessing and navigating the screen. The ANOVA results are summarized in Table 8.

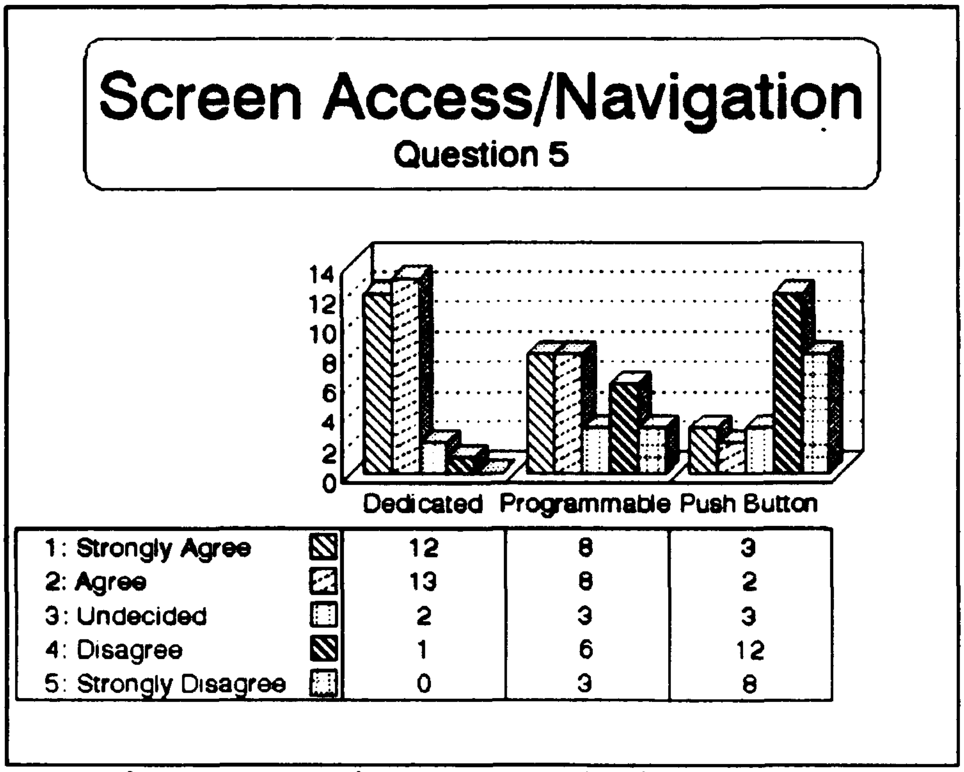


Figure 7. Histogram Depicting Results for Task 1, Question 5

TABLE 8

RESULTS OF THE ANOVA FOR TASK 1, QUESTION 5

Source	**DF**	**SS**	**MS**	**F**	**P**
Between	2	58.3095	29.1547	21.54	0.0000
Within	81	109.642	1.35361		
Total	83	167.952			

Feature	**Mean**	**Std Dev**	**Homogeneous Groups**		
Ded/Hardware	1.7142	0.7629	I		
Programmable	2.6071	1.3700		I	
Push Button	3.7500	1.1634			I

Since the above p-value of 0.0000 is less than the level of significance of 0.05, the overall F-test shows that there are significant differences among the means. The Bonferroni Comparison of Means shows that all three means are significantly different from one another.

Since the mean values are all significantly different and the mean value showing the highest degree of user satisfaction is 1.7142 for the dedicated/hardware keys, the dedicated/hardware keys provided the most user satisfaction overall. The mean value for push button keys is 3.7500, which corresponds to undecided/disagree. Push button keys, therefore, provided the least user satisfaction overall.

Ranked Questions. After each subject completed Task 1, using all three features, they ranked the features according to user satisfaction (1 = best and 3 = worst). Each ranking question corresponds to the five questions already discussed (R1 = Question 1). The results of the rankings are summarized in Figure 8.

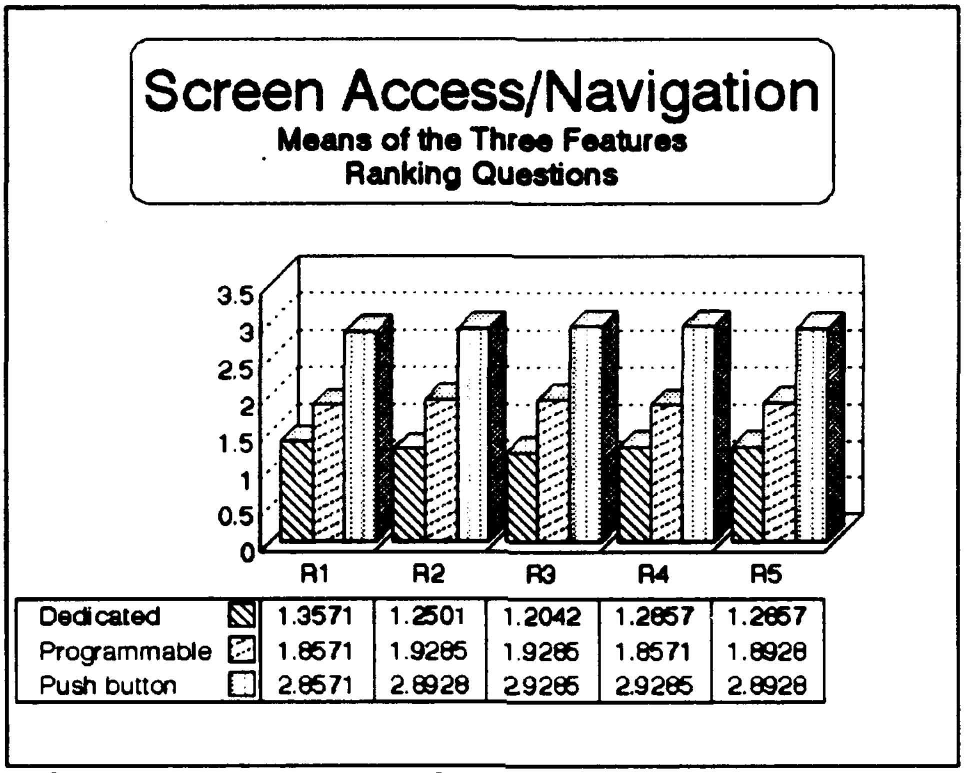


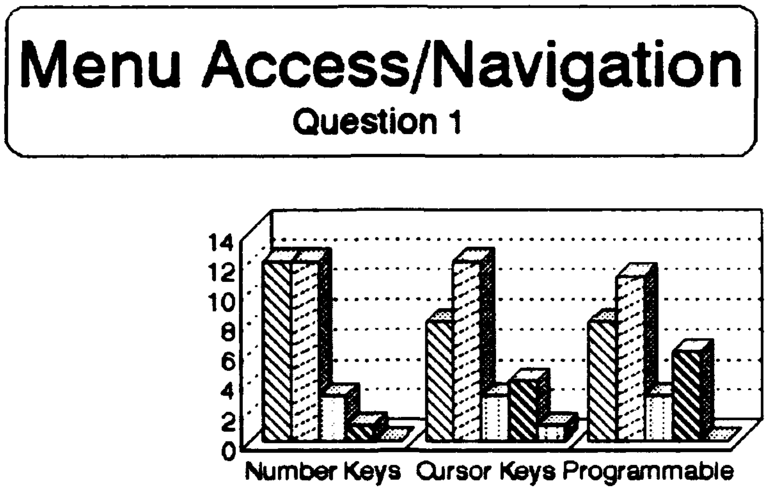
Figure 8. Summary of the Mean Values for the Rankings of the Three Features

Seventy-one percent of the responses selected the dedicated/hardware keys as the best feature and all but two responses selected push button keys as the worst feature. The rankings support the findings from Task 1: The dedicated/hardware keys provided the most user satisfaction overall and the push button keys provided the least user satisfaction overall. The programmable soft keys consistently rated in the middle. Task 2 results are discussed next.

Task 2: Menu Access and Navigation. The features used in this task include: number keys, cursor control keys, and programmable soft keys. Each question from the questionnaire is discussed separately.

Question 1. *The feature provided a high degree of user satisfaction when moving from one screen to the next.* Out of 28 responses, the following rated strongly agree or agree: 24 for the number keys, 20 for the cursor control keys, and 19 for the programmable soft keys. These results indicate that people were satisfied with all three features when moving from one screen to the next (See Figure 9).

To further analyze the results, we performed an analysis of variance (ANOVA) to determine if there were significant differences among the means for all three features. The ANOVA results are summarized in Table 9.



		Number Keys	Cursor Keys	Programmable
1: Strongly Agree	▧	12	8	8
2: Agree	▨	12	12	11
3: Undecided	▥	3	3	3
4: Disagree	▧	1	4	6
5: Strongly Disagree	▦	0	1	0

Figure 9. Histogram Depicting Results for Task 2, Question 1

TABLE 9

RESULTS OF THE ANOVA FOR TASK 2, QUESTION 1

Source	**DF**	**SS**	**MS**	**F**	**P**
Between	2	4.09523	2.04761	2.068	0.1321
Within	81	80.6071	0.99515		
Total	83	84.7023			

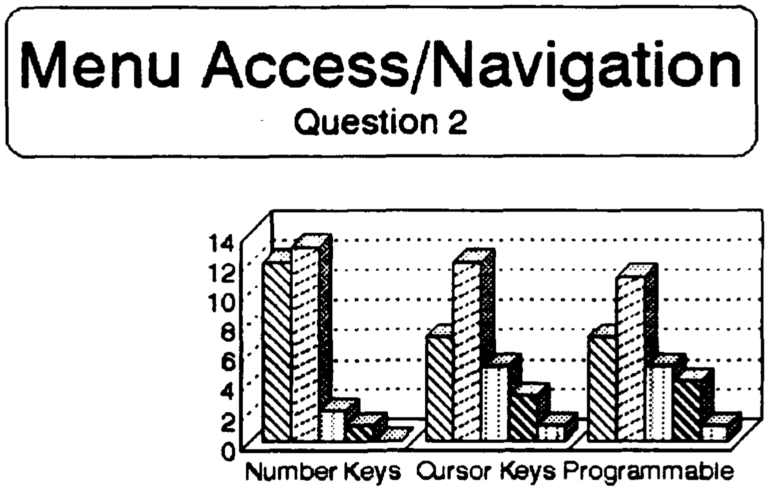
Feature	**Mean**	**Std Dev**	**Homogeneous Groups**		
Number Keys	1.7500	0.7993	I		
Cursor Keys	2.1785	1.0559	I		
Programmable Keys	2.2500	1.1097	I		

To determine if there is a significant difference among the means, we tested the null hypothesis that no significant differences exist. If the p-value is less than the level of significance, then the null hypothesis is rejected and the alternative hypothesis, there are significant differences among the means, is accepted. Since the above p-value of 0.1321 is greater than the level of significance of 0.05, the overall F-test shows that there are no significant differences among the means. Table 9 also summarizes the mean and standard deviation for each feature. We compared the mean values by using the Bonferroni Pairwise Comparison of Means. This comparison shows homogeneous groups, represented by the *I* in the same column. ~f the groups are not homogeneous, the *I*s appear in separate columns. According to the results shown in Table 9, all three means are not significantly different from one another--all features have *I*s in the same column.

Since the mean values correspond to agree/strongly agree and they are not significantly different, all three features provided a high degree of user satisfaction when moving from one main menu item to the next.

Question 2. *The feature provided a high degree of user satisfaction when navigating up and down the submenu items.* Out of the 28 responses, the following rated the features strongly agree or agree: 25 for number keys, 19 for cursor control keys, and 18 for programmable soft keys. These results indicate that people were satisfied with all

three features when navigating up and down the submenu (See Figure 10). The ANOVA results are summarized in Table 10.



	Number Keys	Cursor Keys	Programmable
1: Strongly Agree	12	7	7
2: Agree	13	12	11
3: Undecided	2	5	5
4: Disagree	1	3	4
5: Strongly Disagree	0	1	1

Figure 10. Histogram Depicting Results for Task 2, Question 2

TABLE 10

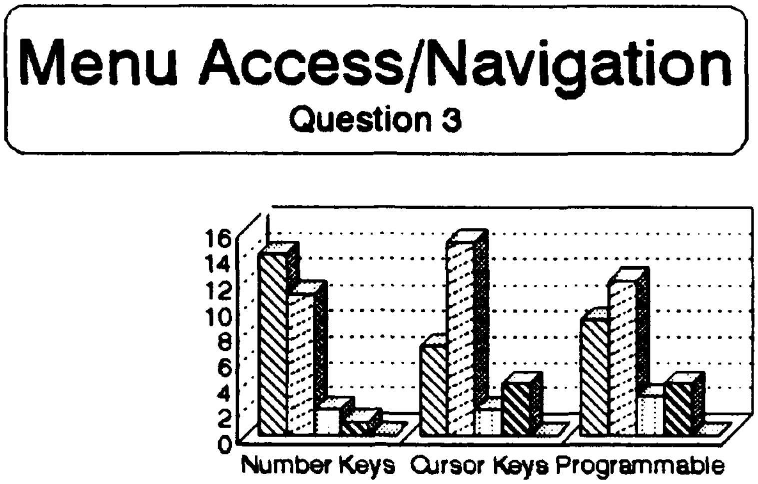
RESULTS OF THE ANOVA FOR TASK 2, QUESTION 2

Source	**DF**	**SS**	**MS**	**F**	**P**
Between	2	5.88095	2.94047	3.110	0.0486
Within	81	76.5357	0.94488		
Total	83	82.4166			

Feature	**Mean**	**Std Dev**	**Homogeneous Groups**		
Number Keys	1.7142	0.7629	I		
Cursor Keys	2.2142	0.9946	I		
Programmable Keys	2.3214	1.1239	I		

Since the p-value of 0.0486 is less than the level of significance of 0.05, the ANOVA indicates that there are some differences among the means; however, using Bonferroni Pairwise Comparison of Means, all three features are not significantly different. This inconsistency exists because the Bonferroni comparison is the most conservative test of difference among means. We conclude that the features are not significantly different. The means of all three features correspond to strongly agree/agree, therefore, all three features provide a high degree of user satisfaction.

Question 3. *Few accessing nd selection errors were made using this feature.* Out of the 28 responses, the following rated the features strongly agree or agree: 25 for number keys, 22 for cursor control keys, and 21 for programmable soft keys. These results indicate that people made few accessing and selection errors when using all three features (See Figure 11). The ANOVA results are summarized in Table 11.



	Number Keys	Cursor Keys	Programmable
1: Strongly Agree	14	7	9
2: Agree	11	15	12
3: Undecided	2	2	3
4: Disagree	1	4	4
5: Strongly Disagree	0	0	0

Figure 11. Histogram Depicting Results for Task 2, Question 3

TABLE 11

RESULTS OF THE ANOVA FOR TASK 2, QUESTION 3

Source	**DF**	**SS**	**MS**	**F**	**P**
Between	2	3.73809	1.86904	2.200	0.1157
Within	81	68.9642	0.85141		
Total	83	72.7023			

Feature	**Mean**	**Std Dev**	**Homogeneous Groups**		
Number Keys	1.6428	0.7800	I		
Cursor Keys	2.1071	0.9560	I		
Programmable Keys	2.0714	1.0157	I		

Since the p-value of 0.1157 is greater than the level of significance of 0.05, the ANOVA indicates that there are no differences among the means. The Bonferroni Pairwise Comparison of Means shows that all three features are not significantly different. The means of all three features correspond to strongly agree/agree, therefore, all three features provide few accessing and selection errors.

Question 4. *Overall, the feature provided a high degree of user satisfaction when accessing and navigating the menu.* Out of the 28 responses, the following rated the features strongly agree or agree: 24 for number keys, 19 for cursor control keys, and 17 for programmable soft keys. This indicates that people experienced a high degree of user satisfaction when using all three features (See Figure 12). The ANOVA results are summarized in Table 12.

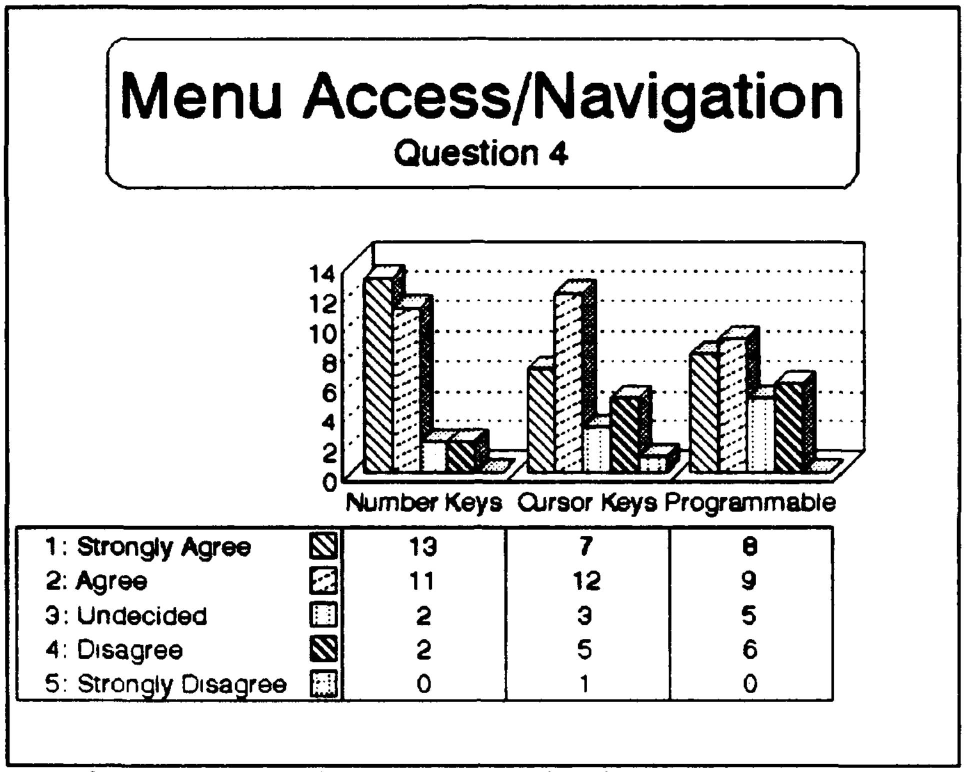


Figure 12. Histogram Depicting Results for Task 2, Question 4

TABLE 12

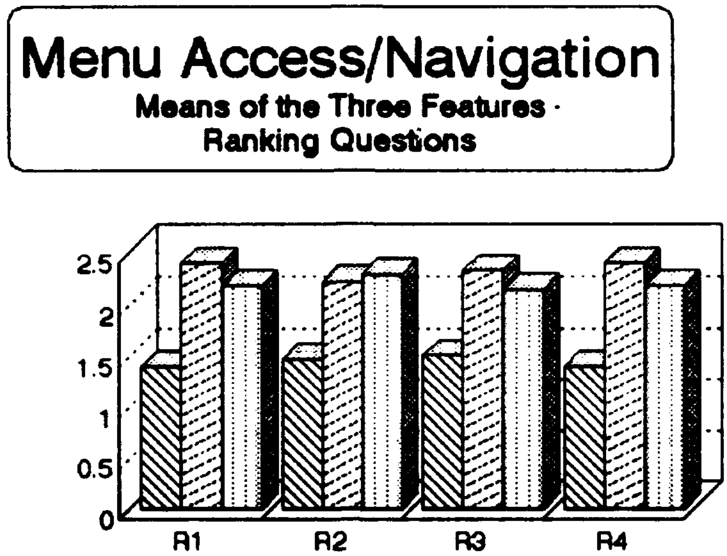
RESULTS OF THE ANOVA FOR TASK 2, QUESTION 4

Source	**DF**	**SS**	**MS**	**F**	**P**
Between	2	6.88095	3.44047	3.170	0.0461
Within	81	87.9285	1.08553		
Total	83	94.8095			

Feature	**Mean**	**Std Dev**	**Homogeneous Groups**		
Number Keys	1.7142	0.8099	I		
Cursor Keys	2.3214	1.1564	I		
Programmable Keys	2.3214	1.1239	I		

Since the p-value of 0.0461 is less than the level of significance of 0.05, the ANOVA indicates that there are some differences among the means; however, using Bonferroni Pairwise Comparison of Means, all three features are not significantly different. This inconsistency exists because the Bonferroni comparison is the most conservative test of difference among means. We conclude that the features are not significantly different. The means of all three features correspond to strongly agree/agree, therefore, all three features provide an overall high degree of user satisfaction.

Ranked Questions. After each subject completed Task 2, using all three features, they ranked the features according to user satisfaction (1 = best and 3 = worst). Each ranking question corresponded to the four questions already discussed (R1 = Question 1). The results of the rankings are summarized in Figure 13.



	R1	R2	R3	R4
Number Keys	1.3929	1.4642	1.5	1.3928
Cursor Keys	2.3928	2.2142	2.3214	2.3928
Programmable	2.1785	2.2857	2.1428	2.1785

Figure 13. Summary of the Mean Values for the Rankings of the Three Features

When forced to make a distinction among the features, 61 percent of the subjects ranked number keys the best. There is no clear distinction between cursor control keys and programmable soft keys. An analysis of the variances and the Bonferroni Pairwise Comparison of Means show a significant difference between number keys and the other two features (See Table 13).

TABLE 13

RESULTS OF THE ANOVA FOR TASK 2, RANKINGS

Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	15.5238	7.76190	15.16	0.0000	
Within	81	41.4642	0.51190			
Total	83	56.9880				
Feature		**Mean**	**Std Dev**	**Homogeneous Groups**		
Number Keys		1.3928	0.4973	I		
Cursor Keys		2.3928	0.7859		I	
Programmable Keys		2.1785	0.8189		I	

According to the analysis in the previous sections, all three features provided a high degree of user satisfaction. Only when the subjects compared the three features did a best feature, number keys, emerge. We conclude that number keys provide the highest degree of user satisfaction when accessing and navigating the menu, and there is no clear difference in user satisfaction between cursor control and programmable soft keys. The next section addresses the seven investigative questions posed in Chapters 1 and 3.

Investigative Questions

This section discusses and answers the seven investigative questions posed in Chapters 1 and 3.

Question 1. *What are the differences in total task completion times among the three features in each main task.* **Table 14 summarizes the ANOVA results for total task completion times for Task 1.**

TABLE 14

RESULTS OF THE ANOVA FOR TOTAL TASK COMPLETION TIMES FOR TASK 1

Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	2.197E05	1.098E05	27.16	0.0000	
Within	81	3.276E05	4044.77			
Total	83	5.473E05				
Feature		**Mean (Secs)**	**Std Dev**	**Homogeneous Groups**		
Ded/Hardware Keys		142.75	51.917	I		
Programmable Keys		175.02	47.215	I		
Push Button Keys		263.71	84.909		I	

The ANOVA and Bonferroni comparison indicate that there are significant differences among the means for total task completion times. These results show that dedicated/hardware keys and programmable soft keys are the same, but both are different from push button keys. Therefore, dedicated/hardware keys and programmable soft

keys provided the fastest total task completion times, while push button keys provided the slowest total task completion times for Task 1.

Table 15 summarizes the ANOVA results for total task completion times for Task 2.

TABLE 15

RESULTS OF THE ANOVA FOR TOTAL TASK COMPLETION TIMES FOR TASK 2

Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	8415.19	4207.59	10.55	0.0001	
Within	81	32313.8	398.936			
Total	83	40929.0				
Feature		**Mean (Secs)**	**Std Dev**	**Homogeneous Groups**		
Number Keys		65.402	17.788	I		
Cursor Keys		89.212	21.961		I	
Programmable Keys		72.244	19.951	I		

The ANOVA and Bonferroni comparison indicate that there are significant differences between number and programmable soft keys and cursor control keys. Therefore, number and programmable soft keys provided the fastest total task completion times, while cursor control keys provided the slowest total task completion times for Task 2.

To answer investigative question 1, both the dedicated/hardware and programmable soft keys provided the fastest total task completion times when accessing/

navigating the screens and both the number and programmable soft keys provided the fastest total task completion times when accessing/navigating the menu.

Question 2. *What are the differences in total key strokes among the three features in each main task?* Table 16 summarizes the ANOVA results for total key strokes for Task 1.

TABLE 16

RESULTS OF THE ANOVA FOR TOTAL KEY STROKES FOR TASK 1

Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	4738.3	23769.1	179.4	0.0000	
Within	81	10734.5	132.524			
Total	83	58272.8				
Feature		**Mean**	**Std Dev**	**Homogeneous Groups**		
Ded/Hardware Keys		52.392	8.4210	I		
Programmable Keys		48.285	4.9729	I		
Push Button Keys		100.67	17.376		I	

The ANOVA and Bonferroni comparison indicate that there are significant differences among the means for total key strokes. These results show that dedicated/hardware keys and programmable soft keys are the same, but both are different from push button keys. Therefore, dedicated/hardware keys and programmable soft keys required the least amount of key strokes, while push button keys required the greatest amount of key strokes for Task 1.

Table 17 summarizes the ANOVA results for total key strokes for Task 2.

TABLE 17

RESULTS OF THE ANOVA FOR TOTAL KEY STROKES FOR TASK 2

Source	**DF**	**SS**	**MS**	**F**	**P**	
Between	2	13862.9	6931.47	722.7	0.0000	
Within	81	776.857	9.59082			
Total	83	14639.8				
Feature		**Mean**	**Std Dev**	**Homogeneous Groups**		
Number Keys		10.714	1.3569	I		
Cursor Keys		37.785	5.1377		I	
Programmable Keys		10.357	0.7310	I		

The ANOVA and Bonferroni comparison indicate that there are significant differences between number and programmable soft keys and cursor control keys. Therefore, number and programmable soft keys required the least amount of key strokes, while cursor control keys required the greatest amount of key strokes for Task 2.

To answer investigative question 2, both the dedicated/hardware and programmable soft keys required the least amount of total key strokes when accessing/navigating the screens and both the number and programmable soft keys the least amount of total key strokes when accessing/ navigating the menu.

Question 3. *What is the correlation between total task completion times and total key strokes?* The correlation between total task completion times and total key strokes for Task 1 is positive, with r = .7226. Correlations range from 1 to -1, with zero indicating no correlation. Since .7226 is close to 1, we conclude there is a high positive correlation between total task completion times and total key strokes. For Task 2, the correlation, r, is 0.4951. This correlation is not as strong as Task 1, but is still significant. We conclude there is a positive correlation between total task completion times and total key strokes for Task 2.

Question 4. *What is the correlation between total task completion times and user satisfaction?* Using the results from the questionnaire to obtain user satisfaction and using the total task completion times, Table 18 summarizes the correlations for the ranking questions.

TABLE 18

SUMMARY OF CORRELATIONS BETWEEN TOTAL TASK COMPLETION TIMES AND USER SATISFACTION

TASK 1					
Question:	Q1	Q2	Q3	Q4	Q5
Correlation	0.5262	0.5769	0.6177	0.5927	0.5781
TASK 2					
Question:	Q1	Q2	Q3	Q4	
Correlation	0.2133	0.1797	0.1497	0.2133	

Table 18 indicates that for Task 1, there is a correlation between total task completion times and user satisfaction. We conclude that the subjects prefer features with the fastest task completion times when accessing/ navigating the screens.

For Task 2, the table indicates that there is a weak correlation between total task completion times and user satisfaction.

Question 5. *What is the correlation between total keystrokes and user satisfaction*? Using the results from the questionnaire to obtain user satisfaction and using the total key strokes, the Table 19 summarizes the correlations for the ranking questions.

TABLE 19

SUMMARY OF CORRELATIONS BETWEEN TOTAL KEY STROKES AND USER SATISFACTION

TASK 1					
Question:	Q1	Q2	Q3	Q4	Q5
Correlation	0.6501	0.6708	0.6833	0.7106	0.6708
TASK 2					
Question:	Q1	Q2	Q3	Q4	
Correlation	0.3105	0.1868	0.2580	0.3105	

Table 19 indicates that for Task 1, there is a correlation between total key strokes and user satisfaction.

We conclude that the subjects prefer features with the least amount of key strokes when accessing/navigating the screens.

For Task 2, Table 19 indicates that there is a weak correlation between total key strokes and user satisfaction. Therefore, total key strokes are not a good indicator of user satisfaction.

Question 6. *Which access/navigation feature provides the most user satisfaction*? As discussed in the Quantitative Analysis section, the dedicated/hardware keys and the number keys provided the most user satisfaction when accessing/navigating the screens and menus, respectively.

Question 7. *What is the statistical difference between non-experienced and experienced computer users when rating the features according to user satisfaction*? Table 20 summarizes the ANOVA results for blocking on computer experience for Task 1.

TABLE 20

RESULTS OF THE TASK 1 ANOVA FOR NON-EXPERIENCED AND EXPERIENCED COMPUTER USERS

Source	**DF**	**SS**	**MS**	**F**	**P**
Experience	1	0.04127	0.04127	0.01	0.92465
Treatments	2	36.1607	18.0804	4.204	0.01798
Within	80	344.047	4.3006		
Total	83	380.2490			

The ANOVA tests the null hypothesis that there are no significant differences between non-experienced and experienced computer users when rating the features for user satisfaction. Since the p-value, 0.92465, for the experience blocking factor is greater than the level of significance, 0.05, we fail to reject the null hypothesis. Therefore, computer experience had no effect on user satisfaction in Task 1.

Table 21 summarizes the ANOVA results for blocking computer experience for Task 2.

TABLE 21

RESULTS OF THE TASK 2 ANOVA FOR
NON-EXPERIENCED AND EXPERIENCED COMPUTER USERS

Source	**DF**	**SS**	**MS**	**F**	**P**
Experience	1	0.11288	0.11288	0.027	0.86988
Treatments	2	8.64285	4.3214	1.041	0.35897
Within	80	332.011	4.1501		
Total	83	340.7667			

Since the p-value, 0.86988, for the experience blocking factor is greater than the level of significance, 0.05, we fail to reject the null hypothesis. Therefore, computer experience had no effect on user satisfaction in Task 2.

Qualitative Analysis

All subjects completed a questionnaire evaluating the access/navigational features for each main task. As stated earlier, the subjects rated, ranked and answered open-ended questions about each feature. This section summarizes the open-ended comments. Task 1, screen access and navigation, evaluated dedicated/hardware, programmable soft, and push button keys.

Dedicated/Hardware Keys. Of the 29 comments on dedicated/hardware keys, 26 were positive and only 3 were negative. The comments had three main themes: easy, fast, and familiar. Thirteen subjects stated that the dedicated/hardware keys were easy to use and understand. "It's easy, straight forward, and less confusing than the other features." Ten subjects commented that the keys were fast and familiar. "Easiest and most familiar of the three features." The three negative comments stated that the dedicated/hardware keys were too slow or required too many key strokes.

Programmable Soft Keys. Of the 32 comments on programmable soft keys, 16 were positive and 16 were negative. Two main positive themes surfaced: easy and good location. Nine subjects stated that the programmable soft keys were easy to understand or use. "Easy, like using function keys to select a menu item." Five subjects liked the location of the keys. "All keys needed were in the same

area, making it easy to access." Three themes surfaced in the negative comments: unfamiliar use of keys, slow, and confusing. Five subjects stated that the keys were being used for functions that they normally are not used for. "Using a function key (programmable soft key) to go up and down is strange; function keys should be used for main menu items." Five subjects stated that the keys were slow and four stated they were confusing. "You had to stop and look at the screen to tell which key would move the cursor in the direction you need. With an arrow key, you know the direction automatically." "Selection was not automatic; you had to think about it."

Push Button Keys. Of the 29 comments about push button keys, 5 were positive and 24 were negative. Three subjects stated they liked the way push button keys highlighted the selection. "Liked being able to watch the cursor highlight the area--easier to make selection with less errors." Three themes surfaced in the negative comments: too many keystrokes, slow, confusing. Nine subjects commented that the push button keys required too many key strokes to accomplish a task. "Excessive number of movements--worst of all functions." "Requires more steps to get the task done." Eight subjects stated that the push buttons were slow and seven stated that they were confusing. "Too slow, too complicated."

The qualitative analysis for Task 1 substantiates the findings in the quantitative analysis section. Dedicated/

hardware keys provided the highest and push button keys provided the lowest degree of user satisfaction when accessing and navigating the screens. Task 2, menu access and navigation, evaluated the following features: number, cursor control, and programmable soft keys.

Number Keys. Of the 34 responses, 28 were positive and 6 were negative. Fourteen subjects stated that the number keys were easy to use and understand. "Numbers were easy to use because they corresponded to the selection number in the menu." Others commented that the number keys were fast and familiar. The main reason people did not like the number keys was because they offered no visual feedback on the selection made. "It didn't show which one I selected."

Cursor Control Keys. Like number keys, subjects felt the cursor control keys were easy. Of the 18 positive responses, 11 subjects commented on their ease of use. Four subjects commented on the visual feedback of the cursor control keys. "I could watch the screen respond to each cursor movement." Of the 15 negative responses, 9 subjects commented that the cursor control keys were too slow and 5 commented that they required too many key strokes. "Not as fast as number or programmable soft keys." "Too slow, have to move the cursor too much."

Programmable Soft Keys. Subjects found the programmable soft keys fast and easy to use. Of the 19 positive responses, 11 commented on the ease of use, and 5 commented on the speed. "Quick and easy to understand."

Of the 15 negative responses, 6 commented on the problem of having to look at the menu at the top of the screen, then the function options at the bottom of the screen, and then the actual key itself. Having to line up all three areas and make a selection was confusing and required concentration. "Did not like having to look at the bottom of the screen to pick function key titles." "Had to keep changing concentration from top to bottom of screen for functions."

The qualitative analysis for Task 2 substantiate the quantitative findings. Number keys provided the highest degree of user satisfaction when accessing and navigating the menu.

Summary

Both the quantitative and qualitative data collected for Task 1 indicate that dedicated/hardware keys clearly provide the highest degree of user satisfaction. In all five questions, the subjects consistently rated dedicated/hardware keys as strongly agree and agree for user satisfaction and fewest selection errors. In contrast, push button keys were consistently rated as strongly disagree or disagree. The distinction among the three features was more evident when the subjects were asked to compare the three features and rank them according to user satisfaction.

Dedicated/hardware keys clearly emerged as the best feature and push button keys as the worst feature.

In the qualitative analysis, many subjects stated that they preferred the dedicated/hardware keys because they were fast, easy, and familiar. This is substantiated by the high correlation between total task completion times and user satisfaction and the high correlation between total key strokes and user satisfaction. This also explains why push button keys were not highly rated because they had the highest task completion times and most key strokes.

In Task 2, no clear distinction emerged among the three features. All three features had mean values corresponding to the strongly agree or agree response. This indicates that all three features provided a high degree of user satisfaction. However, when asked to compare the three features against one another, number keys emerged as the best feature. We conclude that any of the three features can provide a high degree of user satisfaction, but the number keys are the preferred feature.

The qualitative analysis indicates that subjects liked the number keys because they were quick. However, the quantitative analysis shows that there is a weak correlation between total key strokes/task completion times and user satisfaction. We conclude that the number keys were rated the best feature because they had few negative characteristics. Cursor control and programmable soft keys had significant negative characteristics. Cursor control

keys were too slow and required too many keystrokes, while programmable soft keys required the users to focus their attention on too many areas of the screen and keyboard.

There were no significant differences between non-experienced and experience computer users when rating the features for user satisfaction. The results of the experiment clearly indicate that dedicated/hardware keys and number keys provided the highest degree of user satisfaction for their respective tasks for both non-experienced and experienced computer users.

V. Conclusion and Recommendations

Introduction

As stated in Chapters 1 and 2, the Department of Defense is incorporating portable maintenance aids in existing and emerging weapon system programs. PMAs are needed to access maintenance and technical information about a weapon system. Armstrong Laboratory (AL) personnel design maintenance-support prototypes for the Air Force, including PMAs. AL personnel, when designing the PMA, decided to use a graphical user interface for reasons stated in Chapter 2. The current PMA prototype has redundant access and navigational features. The objective of this research was to evaluate access/navigational features of a graphical user interface installed on a PMA to find the feature that provided the highest degree of user satisfaction.

To test the objective an experiment was conducted. The experiment asked subjects to complete two main tasks, screen and menu access and navigation, and evaluate the features according to user satisfaction. Chapter 4 analyzes the results of the experiment. This chapter is divided into four main sections: Summary of Findings, Factors Affecting the Results, Implications of Results, and Recommendations for Follow-on Research. The chapter concludes with a brief summary of the thesis research.

Summary of Findings

The responses to the questionnaire were analyzed in Chapter 4, Findings and Analysis. Table 22 summarizes the results of the four questions relating to the overall user satisfaction (See Appendices C and D).

TABLE 22

SUMMARY OF THE RESULTS OF EXPERIMENT FOR THE FOUR QUESTIONS RELATING TO OVERALL USER SATISFACTION

Task 1: Screen Access/Navigation				
	p-value	**Test Result**	**Homogenous groups**	**Best Feature**
Q5	0.0000	Reject	All are significantly different	Ded/Hardware Keys
R5	0.0000	Reject	All are significantly different	Ded/Hardware Keys
Task 2: Menu Access/Navigation				
	p-value	**Test Result**	**Homogenous groups**	**Best Feature**
Q4	0.0461	Fail to Reject	No significant differences exists	All features provide high degree of user satisfaction
R4	0.0000	Reject	Number Keys are significantly different from cursor and programmable soft keys	Number Keys

The results were tested for significant differences using an analysis of variance and Bonferroni Pairwise Comparison of Means. The comparison tests the null hypothesis that no significant differences exists among the means. The p-value is the probability that the null hypothesis is true.

As Table 22 indicates, the best feature for screen access and navigation is the dedicated/hardware keys. Both question 5 (Q5) and its associated ranking question (R5), show that all three features are significantly different with the dedicated/hardware keys having the lowest mean value. The mean value for dedicated/hardware keys for question 5 was 1.7172, which corresponds to the strongly agree and agree rating for high user satisfaction. Additionally, the mean value for the dedicated/hardware keys for the associated ranking question was 1.2857. This indicates that a significant portion of the subjects rated this feature the best.

The results for the menu access and navigation task had conflicting results. When asked to rate the features strictly on user satisfaction, there were no significant differences, all three features provided a high degree of user satisfaction. All three mean values were between 1.7 and 2.32. These values correspond to strongly agree and agree ratings for high user satisfaction. However, when subjects ranked the three features, significant differences emerged. For this ranking question, the mean value for

number keys was 1.3928, indicating that a significant portion of the subjects rated this feature the best.

Factors Affecting the Results

Several factors affected the results of the experiment, including the laptop computer, computer program, environment, learning curve, and screen information. We used a laptop computer instead of the prototype PMA because of the modified computer screens needed for the experiment. The laptop had several differences from the PMA.

Laptop Computer. The laptop computer has a fully functional keyboard, whereas the PMA has a limited keyboard (See Figure 14 and 15). Currently, the PMA does not have text keys for inputting letters. The PMA design forces the technician to type in text by first accessing a screen with letters, then using a cursor to highlight the letter needed. The technician keeps highlighting letters until the word is spelled. This design is obviously slower than the laptop computer, which has a full alpha-numeric keyboard. The layout and size of the keys are also different, as seen in Figures 14 and 15. On the PMA, the programmable soft keys are farther apart and larger than the programmable soft keys on the laptop computer. Both these factors could have affected the results of the experiment.

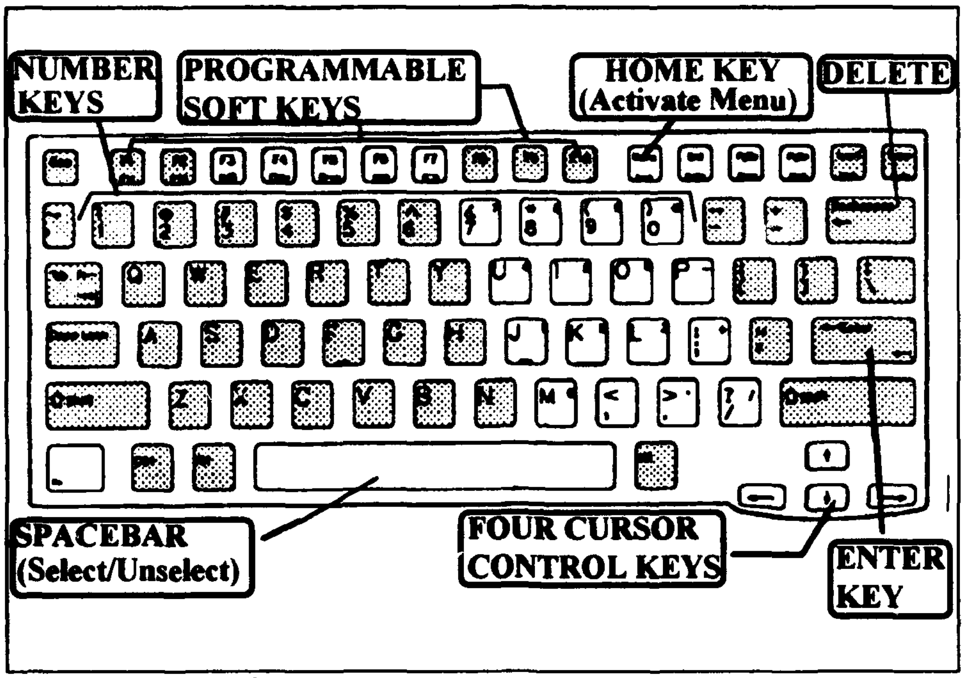


Figure 14. Laptop Keyboard

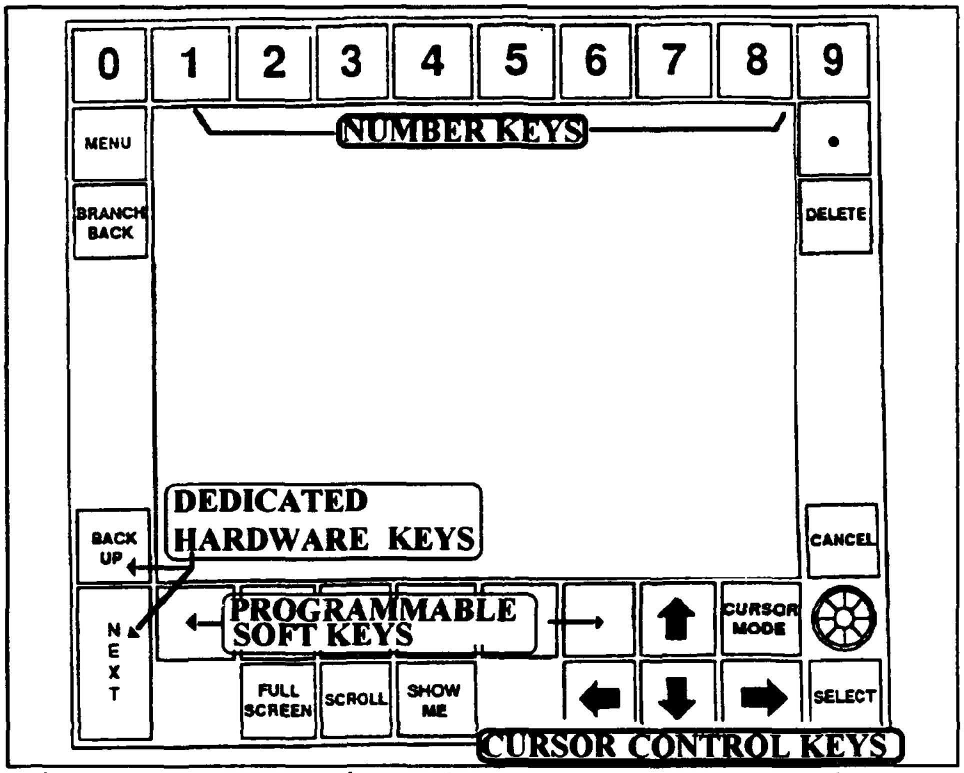


Figure 15. Location of Key Components on the PMA (Eagle Technology, 1991:3)

Computer Program. The computer program had some limitations that could have affected the results of the experiment. The computer program was written in Visual Basic 2.0 for Windows. The program did not allow the user to move laterally on two selection tasks in Task 1, instead users had to use the up or down key to access the items. Subjects found the lack of lateral movement an annoyance, but since all features were tested under the same screens, it should not have affected the results adversely. Another factor that could have affected the results was the speed of the program itself. Subjects complained that the screen speed was slow when using cursor keys. The screen redraw rates were slow because of software and hardware limitations. Also there were some complaints that the cursor keys were slow to respond after some key inputs.

Environment. The PMAs are slated to be used on the flightline for technicians to use to access technical information. The experiment took place in a maintenance back shop, the avionics shop. This environmental artificiality may have affected the experiment because we did not have to deal with the outside elements.

Learning Curve. The learning curve during the experiment was obvious. After running through one or two subtasks, subjects became familiar with the computer, the screens, and the experiment. This is known as the recency effect. The familiarity gave them confidence and their speed usually increased. We tried to counteract the recency

effect by randomizing the task and subtask order, and changing the screen selections to minimize the risk of subjects not reading the screen directions because they remembered the directions from the last subtask. However, we do not feel their opinion of the features were affected by the recency effect. On the contrary, subjects had definite opinions on what features they liked, especially in Task 1. The correlation between task order and responses was weak in both tasks.

Screen Information. The researchers used actual screens from the F/A-18 technical information to develop the screens for the experiment. AL uses F/A-18 technical information on the prototype PMA. The screens were modified for the experiment. In doing so, much of the complex information was replaced with more simplistic information. The tasks were slightly modified to delete unnecessary screens. Since the subjects were evaluating access/navigational features and not maintenance technical data, the modified F/A-18 screens should have affected the experiment only slightly.

Despite the above factors, the experiment provides information about access/navigational features that can be used in the field.

Implications of Results

Results from the experiment show that dedicated/ hardware keys provide the highest degree of user satisfaction when accessing and navigating screens and number keys provide the highest degree of user satisfaction when accessing and navigating the menu. Push button keys and programmable soft keys provided the lowest degree of user satisfactions when accessing and navigating the screens and menu, respectively. These results have important implications for future and emerging weapon systems.

According to AL personnel, the F-22 program is considering using a PMA that relies heavily on programmable soft keys (Masquelier, 1993). Our research does not support this decision. In Task 1, screen access and navigation, the programmable soft keys ranked second behind the dedicated/hardware keys. Subjects did not like using the programmable soft keys because their function was not consistent with what they were already familiar with. In Task 2, menu access and navigation, the programmable soft keys were ranked behind dedicated/hardware keys. Subjects did not like using the programmable soft keys when accessing and navigating the menu because they had to focus their attention on too many areas: the menu itself, the function option, and the actual key. The research suggests that dedicated/hardware and number keys should be incorporated on future PMAs, given the options we tested.

Recommendations for Follow-on Research

This experiment demonstrated that dedicated/hardware keys and number keys provide a high degree of user satisfaction when accessing and navigating screens and menus. However, there are still many areas that should be tested before an operational PMA is fielded. Possible research areas include the use of different input devices on the PMA. Possible input devices include the mouse, light pen, trackball, and touchscreen. According to AL personnel, the B-2 program personnel are investigating the use of touchscreens for their PMA (Masquelier, 1993). The different input devices may affect how users feel about the six access/navigational features tested in this experiment. For example, push buttons were rated the worst feature, but might be rated higher if the user uses a touchscreen or mouse. Additionally, there are other access/navigational features that could be tested in addition to the six tested in this experiment.

Another possible area of research is to compare the performances of maintenance technicians when using a PMA versus an in-shop workstation, incorporating the same interface. Under the IMIS concept, the same interface is used on the PMA and workstation so the user has to learn only one computer system. A test to see if performance differences exist might result in slightly different interfaces for the two computer systems.

As stated earlier, there are many factors that may have affected the results. Possible areas of future research would be to vary these factors to test for significant differences. One factor that could be tested is the environment. This experiment used a controlled environment. However, the PMA is to be used on the flightline, where many adverse conditions exists. Using the same PMA, a comparison of performances could be made by testing the PMA features in both environments--in-shop and flightline.

During the experiment, many subjects commented on using laptops on the flightline. Many favored the use of laptops versus a PMA produced by the DoD. Since a prototype PMA exists, a comparison of technical information on a laptop computer versus a prototype PMA could be conducted. The implications from this research might lead the DoD to procure commercially-available hardware, rather than producing their own.

Summary

In line with the CALS initiative, portable maintenance aids (PMAs) are being developed to store and access technical information on the flightline. The Armstrong Laboratory located at Wright Patterson AFB, OH, mission is to design maintenance support prototypes for the Air Force. One of the laboratory's projects is to develop a prototype PMA. The PMA incorporates a graphical user interface (GUI).

The GUI was developed in accordance with military specifications, the IETM-GCSFUI. There are access/ navigational features used with the PMA that have never been tested for user satisfaction.

Armstrong Laboratory personnel requested research be performed to determine the best access/navigational feature --the feature that provides the highest degree of user satisfaction. The experiment was divided into two main tasks: screen access and navigation evaluating dedicated/hardware keys, programmable soft keys, and push button keys; and menu access and navigation evaluating number keys, cursor control keys, and programmable soft keys.

Screens from the prototype PMA were modified to test the access/navigational features one-at-a-time using a laptop personal computer. Twenty-eight maintenance technicians performed the experiment. They were asked to rate and rank each feature according to user satisfaction. The best feature for screen access and navigation was the dedicated/hardware keys and the best feature for menu access and navigation was the number keys. These results have important implications because the F-22 program is relying heavily on programmable soft keys on their PMAs. This experiment tested six access/navigational features installed on the PMA; however, more research should be conducted before the DoD/Air Force decides on a standard interface design for the PMA.

Appendix A: Acronyms

ACALS - Army CALS

AFHRL - Air Force Human Resource Laboratory

AIMS - Advanced Tactical Fighter Integrated Maintenance Information System

AIP - Aircraft Interface Panel

AL - Armstrong Laboratory

ANOVA - Analysis of Variances

ATDPS - Automated Technical Data Presentation System

ATOS - Automated Technical Order System

CALS - Computer-aided Acquisition and Logistic Support System

CAMS - Core Automated Maintenance System

CEMS - Comprehensive Engine Management System

CMAS - Computer-based Maintenance Aids System

DOD - Department of Defense

EDMICS - Engineering Data Management Information and Control System

GCSFUI - General Content, Style, Format, and User-Interactions Requirements

GUI - Graphical User Interface

HMDD- Head Mounted Display Device

IETM - Interactive Electronic Technical Manuals

IMIS - Integrated Maintenance Information System

J-CALS - Joint-CALS

JUSTIS - Joint Uniformed Service and Technical Information System

MIW - Maintenance Information Workstation

PMA - Portable Maintenance Aid

TO - Technical Orders

Appendix B: Sample Background Survey

NAME: ______________________________

1. Check one: ____ Military ____ Civilian

   ____ Male ____ Female

2. Age ______

3. Total active military service ______ yrs ______ months

4. Current pay grade/rank _____

5. Current job specialty or rating

____

6. Prior work experience, last two jobs:

   a). Career/Occupation specialty________________________
   Location ________________________
   Inclusive dates (m/y) _____/_____ to _____/_____

   b). Career/Occupation specialty________________________
   Location ________________________
   Inclusive dates (m/y) _____/_____ to _____/_____

7. Computer/Electronic experience:

   a). How many years/months computer experience do you have?
   ______ yrs ______ months

   b). Have you ever received formalized computer training? ____Yes ____No

   If yes, what training and for how long? __________
   ____

   c). If you never received formalized training, would you consider yourself self-taught? ____Yes ____No

If yes, what system did you learn on? ___________

d). Do you own your own computer? ____Yes ____No

If yes, what model/type? ________________________

e). Do you use a computer at work? ___Yes ____No

If yes, what model/type? _________________________

f). How many hours a week do you use a computer?
______ hours

g). What do you use the computer for the majority of the time? (ie: word processing, computer games, finances, spread sheets, e-mail etc.)

____

h). Please list the top three programs you use (either at work or home) and specify the operating systems (DOS, Windows, MAC, Amiga, UNIX etc.) Example: Wordperfect for Windows or Word for MAC.
1). ___________________________________
2). ___________________________________
3). ___________________________________

i). Of the following devices and software, check those you have personally used and are familiar with:

____ keyboard	____ text editor
____ numeric key pad	____ word processor
____ mouse	____ file manager
____ light pen	____ electronic spreadsheet
____ touch screen	____ electronic mail
____ track ball	____ computer games
____ joy stick	____ video games
____ other, please specify	

j). Please write any other comments below:

Appendix C: Task 1 Sample Questionnaire

ID #__________

User Evaluation Questionnaire

I. Questions for Task 1: Screen Access and Navigation

Please answer the following questions based on your participation in **TASK 1.** After reading the question circle the number corresponding to your choice.

ID #__________

DEDICATED/HARDWARE KEYS:

1. The dedicated keys provided a high degree of user satisfaction when moving from one screen to the next.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

2. The dedicated keys provided a high degree of user satisfaction when navigating up and down the screen.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

3. The dedicated keys provided a high degree of user satisfaction when moving from one line to the next, after inputting text.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

4. Few accessing and selection errors were made using the dedicated keys.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

5. Overall, the dedicated keys provided a high degree of user satisfaction when accessing and navigating the screens.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

6. What did you like about this access feature?

7. What did you <u>not</u> like about this access feature?

ID #__________

PROGRAMMABLE SOFT KEYS:

1. The programmable soft keys provided a high degree of user satisfaction when moving from one screen to the next.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

2. The programmable soft keys provided a high degree of user satisfaction when navigating up and down the screen.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

3. The programmable soft keys provided a high degree of user satisfaction when moving from one line to the next, after inputting text.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

4. Few accessing and selection errors were made using the programmable soft keys.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

5. Overall, the programmable soft keys provided a high degree of user satisfaction when accessing and navigating the screens.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

6. What did you like about this access feature?

7. What did you <u>not</u> like about this access feature?

ID #__________

PUSH BUTTON KEYS:

1. The push button keys provided a high degree of user satisfaction when moving from one screen to the next.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

2. The push button keys provided a high degree of user satisfaction when navigating up and down the screen.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

3. The push button keys provided a high degree of user satisfaction when moving from one line to the next, after inputting text.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

4. Few accessing and selection errors were made using the push button keys.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

5. Overall, the push button keys provided a high degree of user satisfaction when accessing and navigating the screens.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

6. What did you like about this access feature?

7. What did you <u>not</u> like about this access feature?

ID #__________

II. Questions Evaluating All Three Features

Please answer the following questions based on your completion of **TASK 1**. After reading the question, rank the three access features from best (1) to worst (3).

1. Which feature provided the highest degree of user satisfaction when moving from one screen to the next?

____Dedicated/Hardware Keys

____Programmable Soft Keys

____Push Button Keys

2. Which feature provided the highest degree of user satisfaction when navigating up and down the screen?

____Dedicated/Hardware Keys

____Programmable Soft Keys

____Push Button Keys

3. Which feature provided the highest degree of user satisfaction when moving from one line to the next, after inputting text?

____Dedicated/Hardware Keys

____Programmable Soft Keys

____Push Button Keys

4. Which feature caused the fewest access and selection errors?

____Dedicated/Hardware Keys

____Programmable Soft Keys

____Push Button Keys

5. Overall, which feature provided the highest degree of user satisfaction when accessing and navigating the screens.

____Dedicated/Hardware Keys

____Programmable Soft Keys

____Push Button Keys

ID #__________

6. If you have a preference, which computer access feature did you prefer and why?

7. Did your access preference work best in all task steps? If no, which steps did it not work best in?

8. Would another computer access feature be more practical? If yes, please name the access feature.

9. What advantages would your suggested computer access feature (from question #8) have over the tested access features?

10. What recommendations do you have to improve future experiments?

11. Do you have any other comments about this experiment?

Appendix D: Task 2 Sample Questionnaire

ID #__________

User Evaluation Questionnaire

I. **Questions for Task 2: Menu Access and Navigation**

Please answer the following questions based on your participation in **TASK 2**. After reading the question circle the number corresponding to your choice.

ID #__________

NUMBER KEYS:

1. The number keys provided a high degree of user satisfaction when moving from one main menu item to the next.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

2. The number keys provided a high degree of user satisfaction when navigating up and down the sub-menu items.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

3. Few accessing and selection errors were made using the number keys.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

4. Overall, the number keys provided a high degree of user satisfaction when accessing and navigating the menu.

   1. Strongly Agree
   2. Agree
   3. Undecided
   4. Disagree
   5. Strongly Disagree

5. What did you like about the access feature?

6. What did you <u>not</u> like about the access feature?

ID #__________

CURSOR CONTROL KEYS:

1. The cursor control keys provided a high degree of user satisfaction when moving from one main menu item to the next.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

2. The cursor control keys provided a high degree of user satisfaction when navigating up and down the sub-menu items.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

3. Few accessing and selection errors were made using the cursor control keys.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

4. Overall, the cursor control keys provided a high degree of user satisfaction when accessing and navigating the menu.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

5. What did you like about the access feature?

6. What did you <u>not</u> like about the access feature?

ID #__________

PROGRAMMABLE SOFT KEYS:

1. The programmable soft keys provided a high degree of user satisfaction when moving from one main menu item to the next.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

2. The programmable soft keys provided a high degree of user satisfaction when navigating up and down the sub-menu items.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

3. Few accessing and selection errors were made using the programmable soft keys.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

4. Overall, the programmable soft keys provided a high degree of user satisfaction when accessing and navigating the menu.

    1. Strongly Agree
    2. Agree
    3. Undecided
    4. Disagree
    5. Strongly Disagree

5. What did you like about the access feature?

6. What did you <u>not</u> like about the access feature?

ID #__________

II. Questions Evaluating All Three Features

Please answer the following questions based on your completion of **TASK 2**. After reading the question, rank the three access features from best (1) to worst (3).

1. Which feature provided the highest degree of user satisfaction when moving from one main menu item to the next?

____Number Keys

____Cursor Keys

____Programmable Soft Keys

2. Which feature provided the highest degree of user satisfaction when navigating up and down the sub-menu items?

____Number Keys

____Cursor Keys

____Programmable Soft Keys

3. Which feature caused the fewest access and selection errors?

____Number Keys

____Cursor Keys

____Programmable Soft Keys

4. Overall, which feature provided the highest degree of user satisfaction when accessing and navigating the menu.

____Number Keys

____Cursor Keys

____Programmable Soft Keys

ID #__________

5. If you have a preference, which computer access feature did you prefer and why?

6. Did your access preference work best in all task steps? If no, which steps did it not work best in?

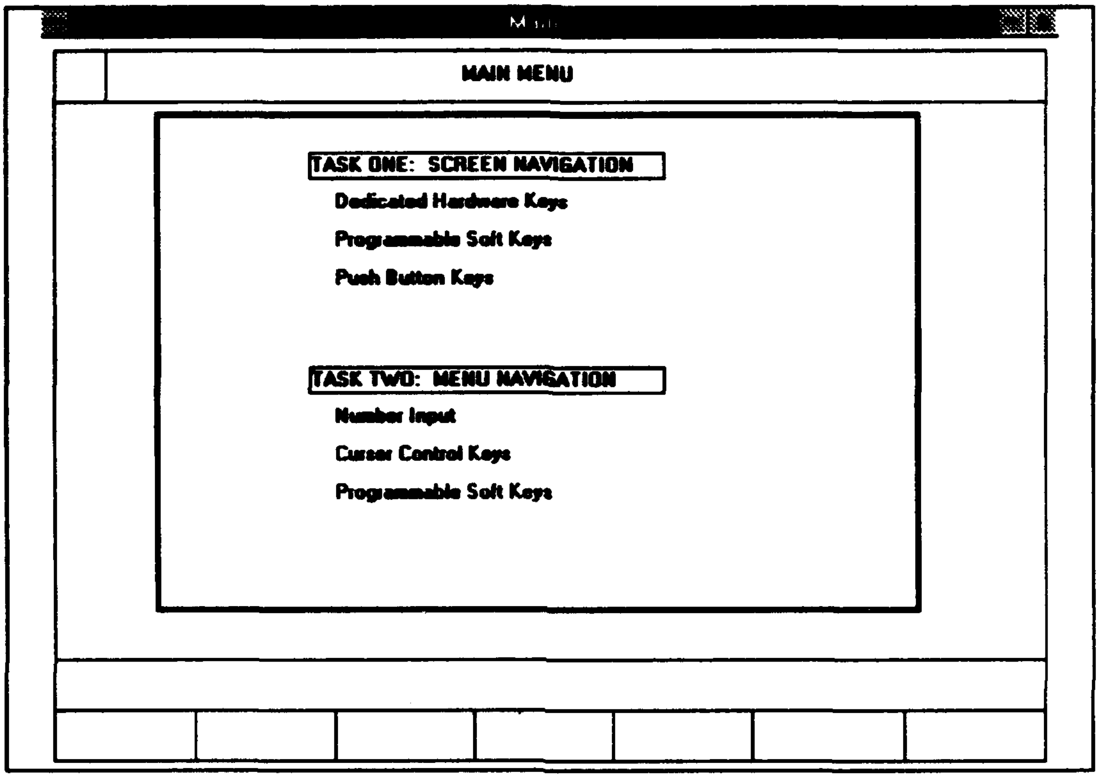
7. Would another computer access feature be more practical? If yes, please name the access feature.

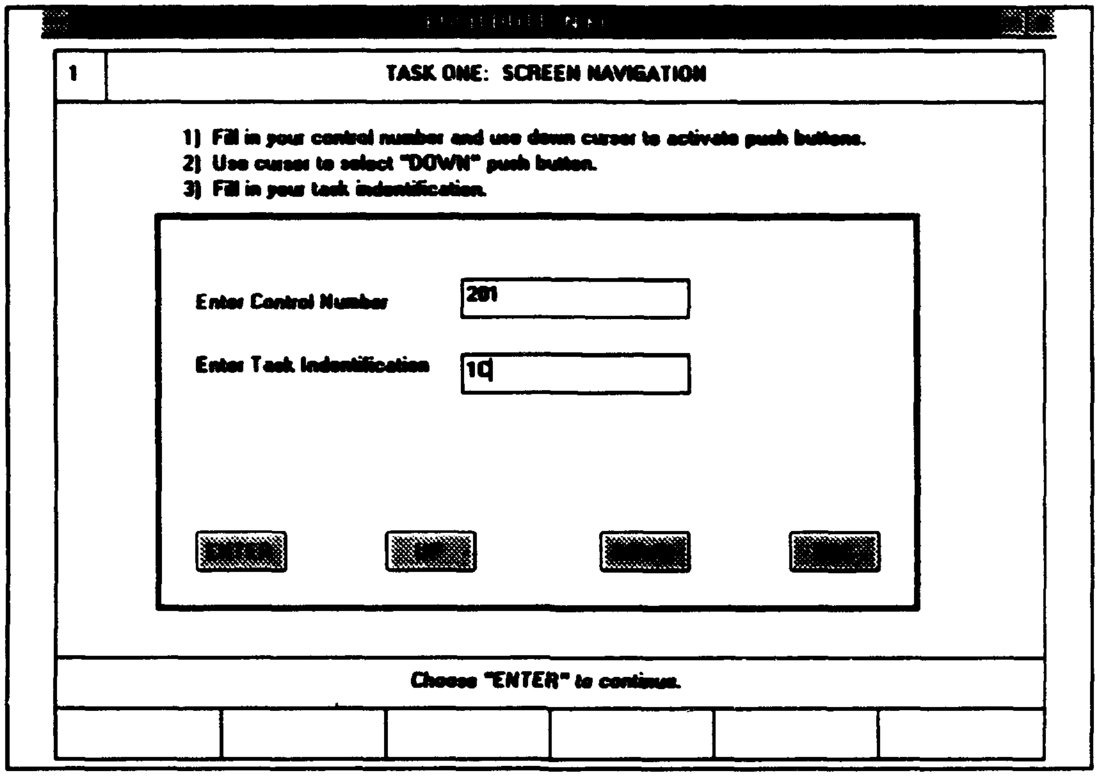
8. What advantages would your suggested computer access feature (from question #7) have over the tested access features?

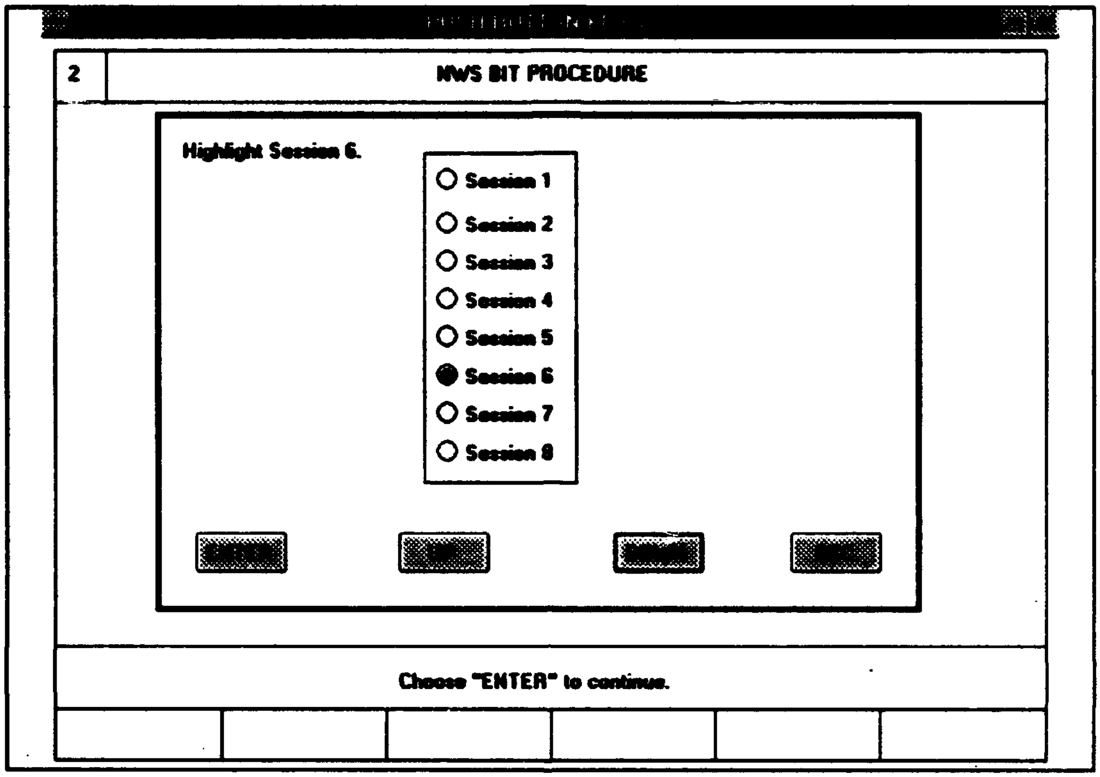
9. What recommendations do you have to improve future experiments?

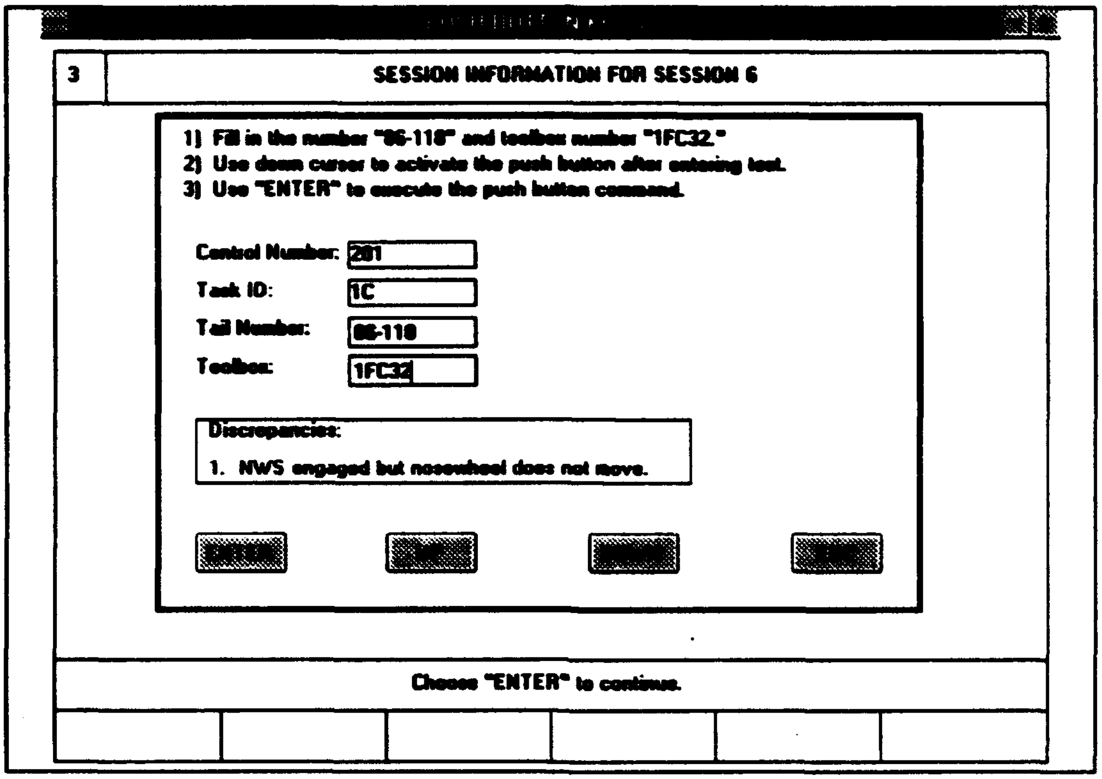
10. Do you have any other comments about this experiment?

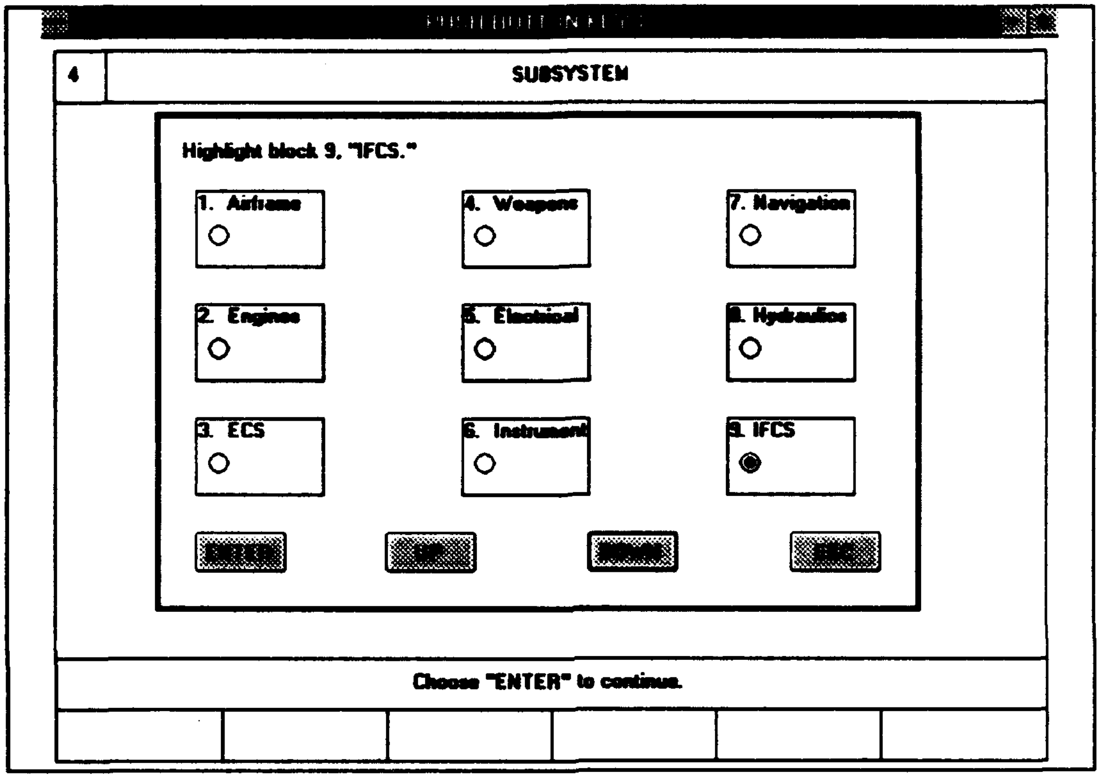
Appendix E: Task 1 Description and Screens

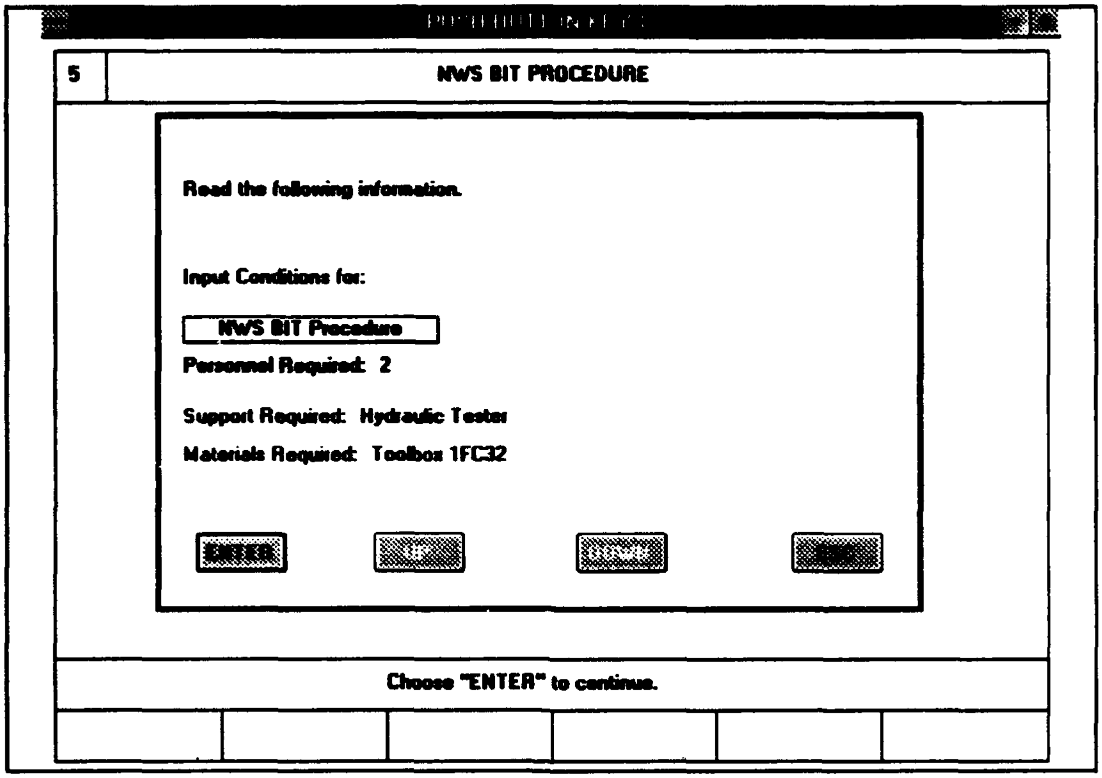


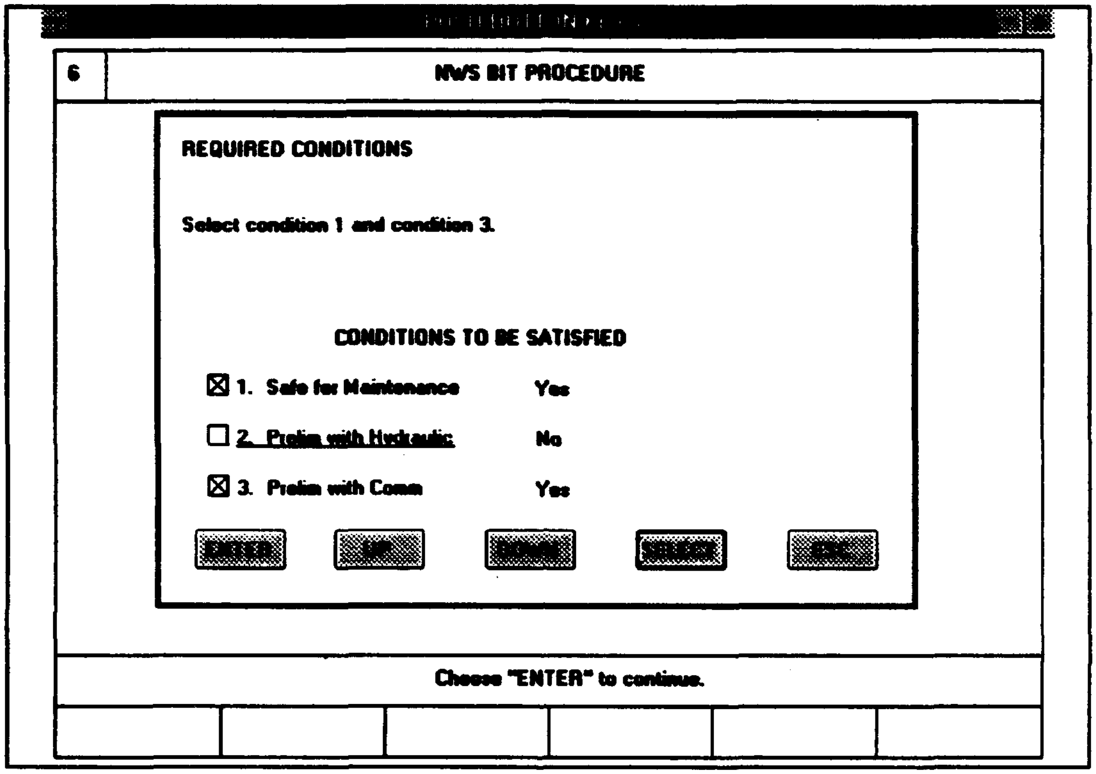

1
TASK ONE: SCREEN NAVIGATION
1) Fill in your control number and use down cursor to activate push buttons.
2) Use cursor to select "DOWN" push button.
3) Fill in your task indentification.
Enter Control Number
201
Enter Task Indentification
1C
Choose "ENTER" to continue.

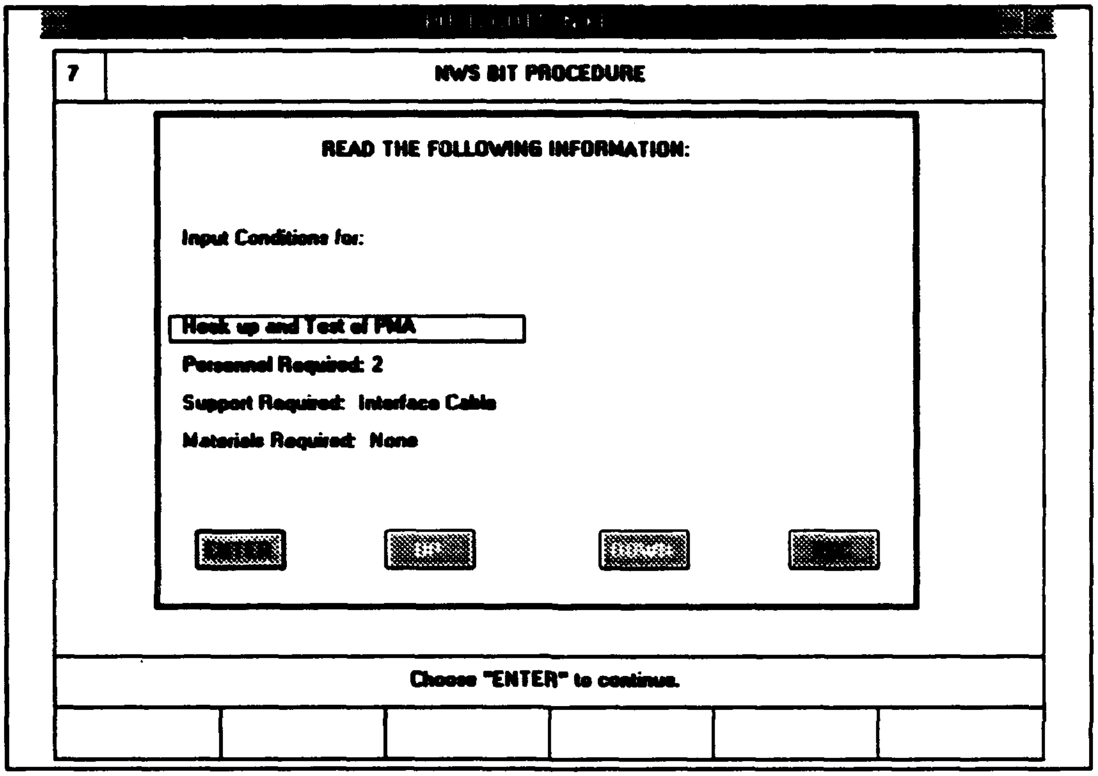

2
NWS BIT PROCEDURE
Highlight Session 6.
Session 1
Session 2
Session 3
Session 4
Session 5
Session 6
Session 7
Session 8
Choose "ENTER" to continue.

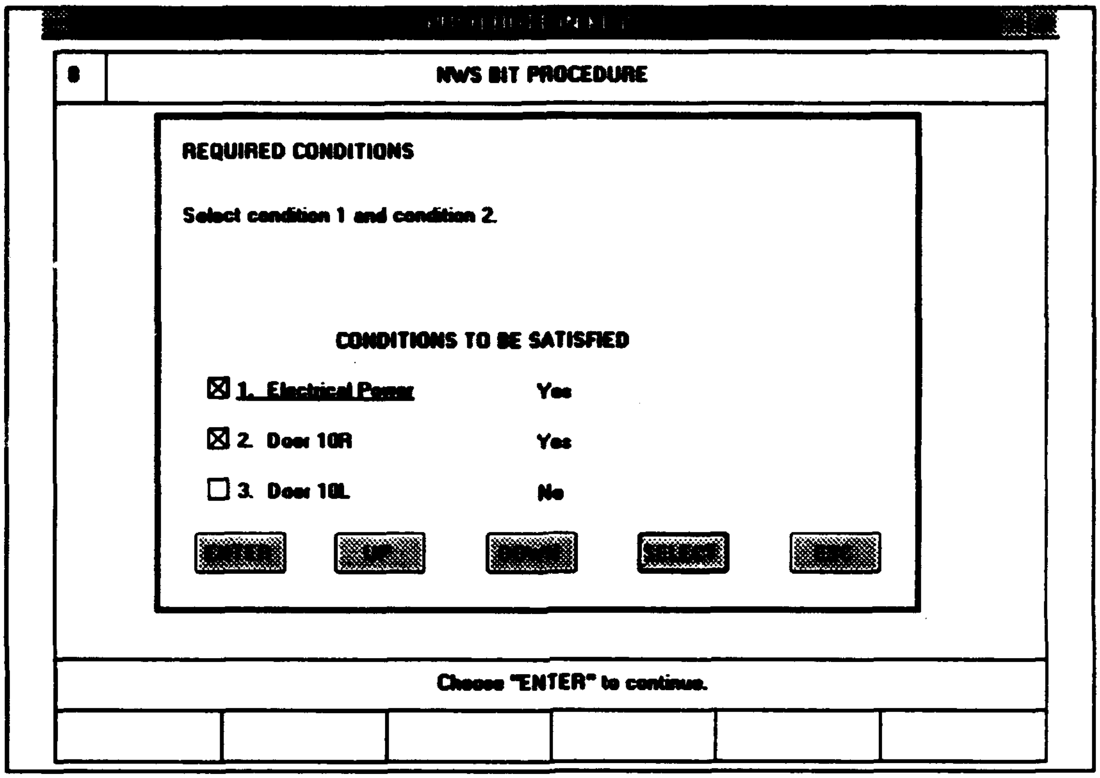

3
SESSION INFORMATION FOR SESSION 6
1) Fill in the number "86-118" and toolbox number "1FC32."
2) Use down cursor to activate the push button after entering text.
3) Use "ENTER" to execute the push button command.
Control Number: 201
Task ID: 1C
Tail Number: 86-118
Toolbox: 1FC32
Discrepancies:
1. NWS engaged but nosewheel does not move.
Choose "ENTER" to continue.

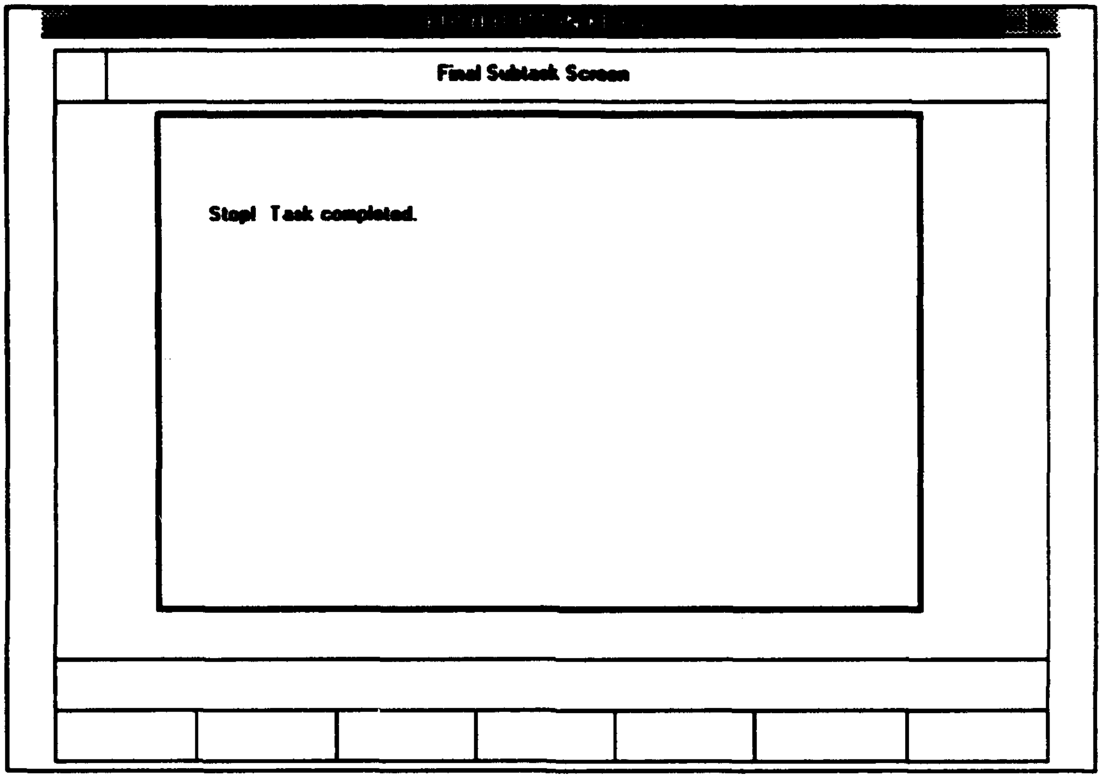

4
SUBSYSTEM
Highlight block 9, "IFCS."
1. Airframe
4. Weapons
7. Navigation
2. Engines
5. Electrical
8. Hydraulics
3. ECS
6. Instrument
9. IFCS
Choose "ENTER" to continue.


5
NWS BIT PROCEDURE
Read the following information.
Input Conditions for:
NWS BIT Procedure
Personnel Required: 2
Support Required: Hydraulic Tester
Materials Required: Toolbox 1FC32
ENTER
Choose "ENTER" to continue.

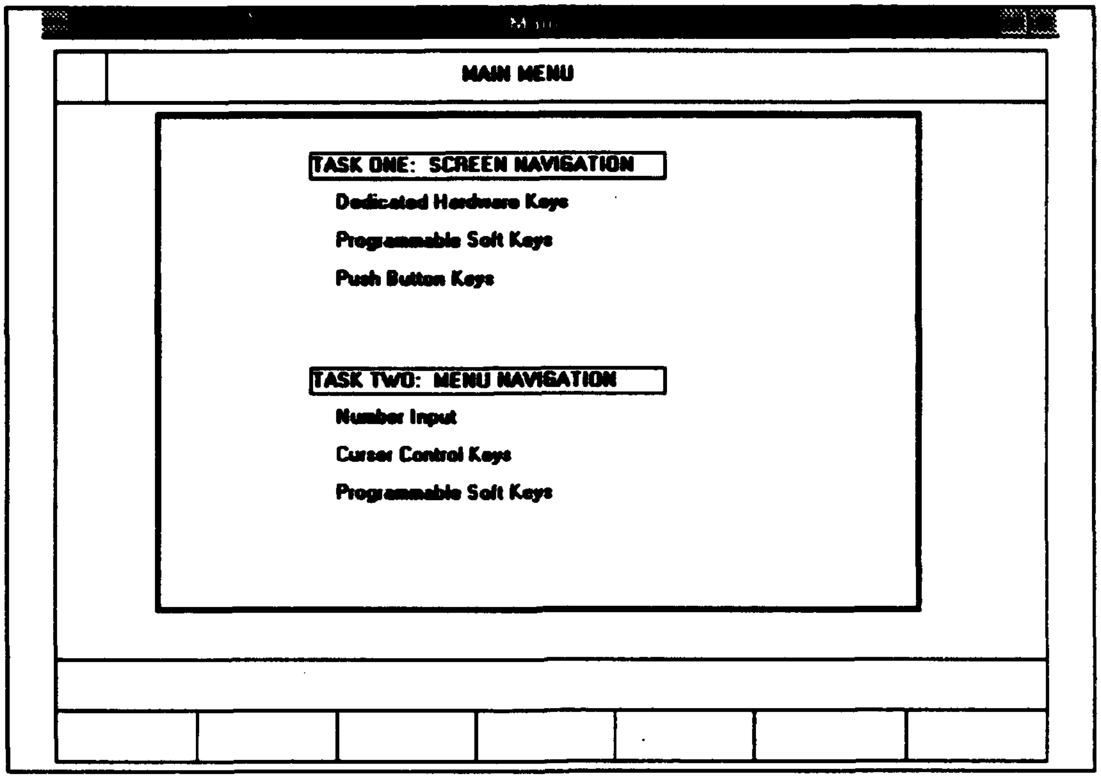

6
NWS BIT PROCEDURE
REQUIRED CONDITIONS
Select condition 1 and condition 3.
CONDITIONS TO BE SATISFIED
1. Safe for Maintenance Yes
2. Prelim with Hydraulic No
3. Prelim with Comm Yes
Choose "ENTER" to continue.

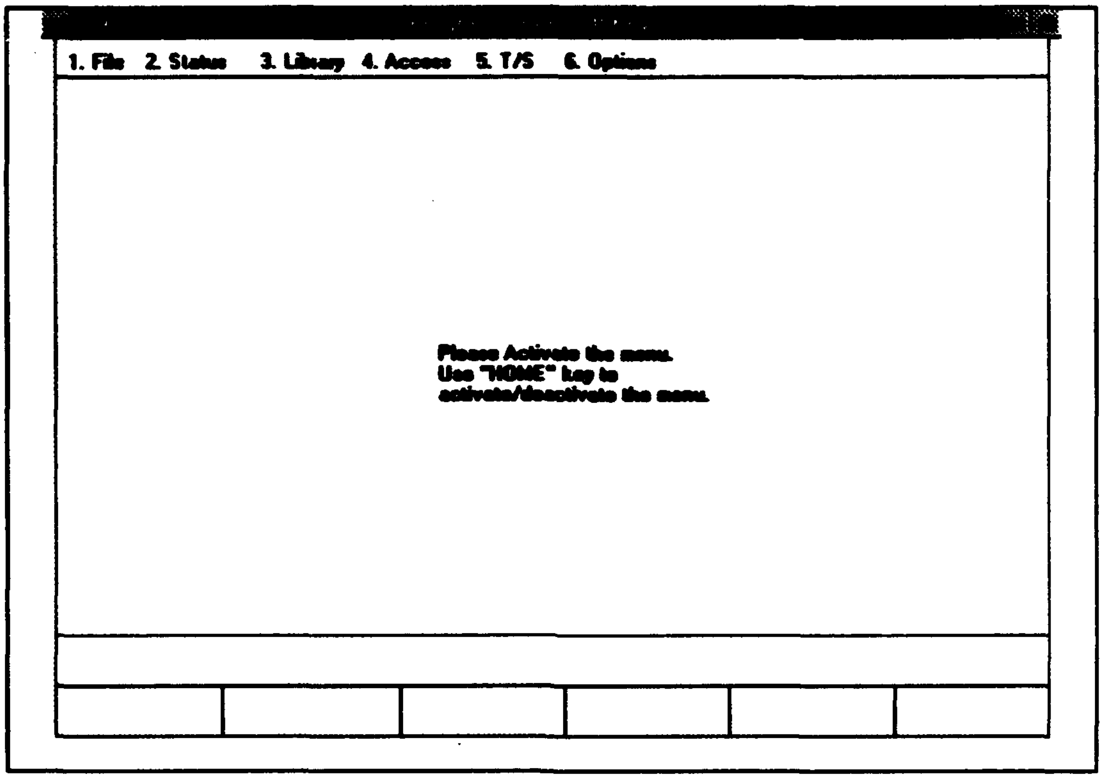

7
NWS BIT PROCEDURE
READ THE FOLLOWING INFORMATION:
Input Conditions for:
Hook up and Test of PMA
Personnel Required: 2
Support Required: Interface Cable
Materials Required: None
Choose "ENTER" to continue.

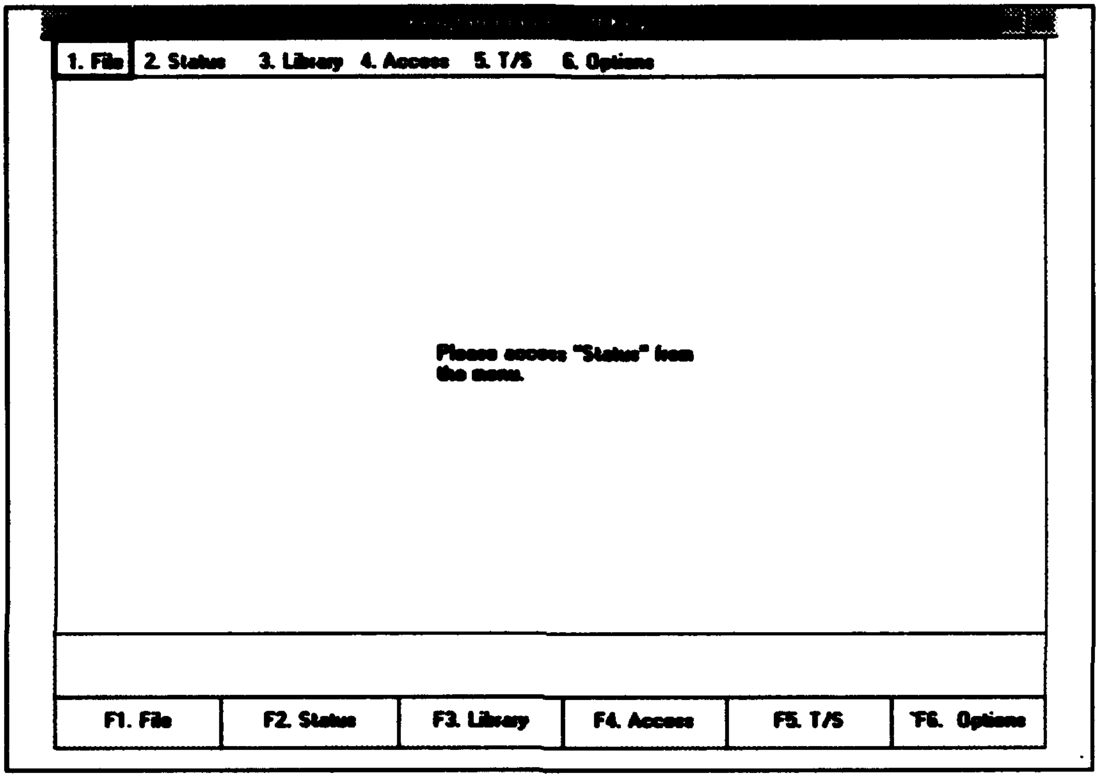

8
NWS BIT PROCEDURE
REQUIRED CONDITIONS
Select condition 1 and condition 2.
CONDITIONS TO BE SATISFIED
1. Electrical Power Yes
2. Door 10R Yes
3. Door 10L No
Choose "ENTER" to continue.

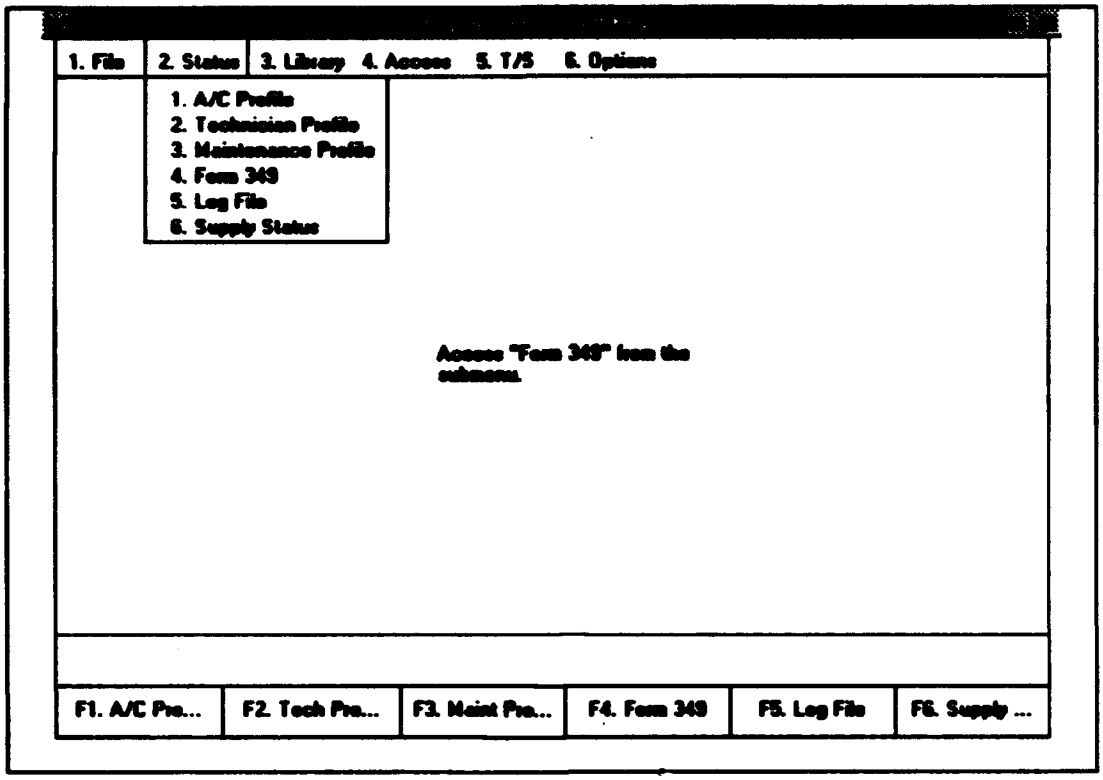

Final Subtask Screen
Stop! Task completed.

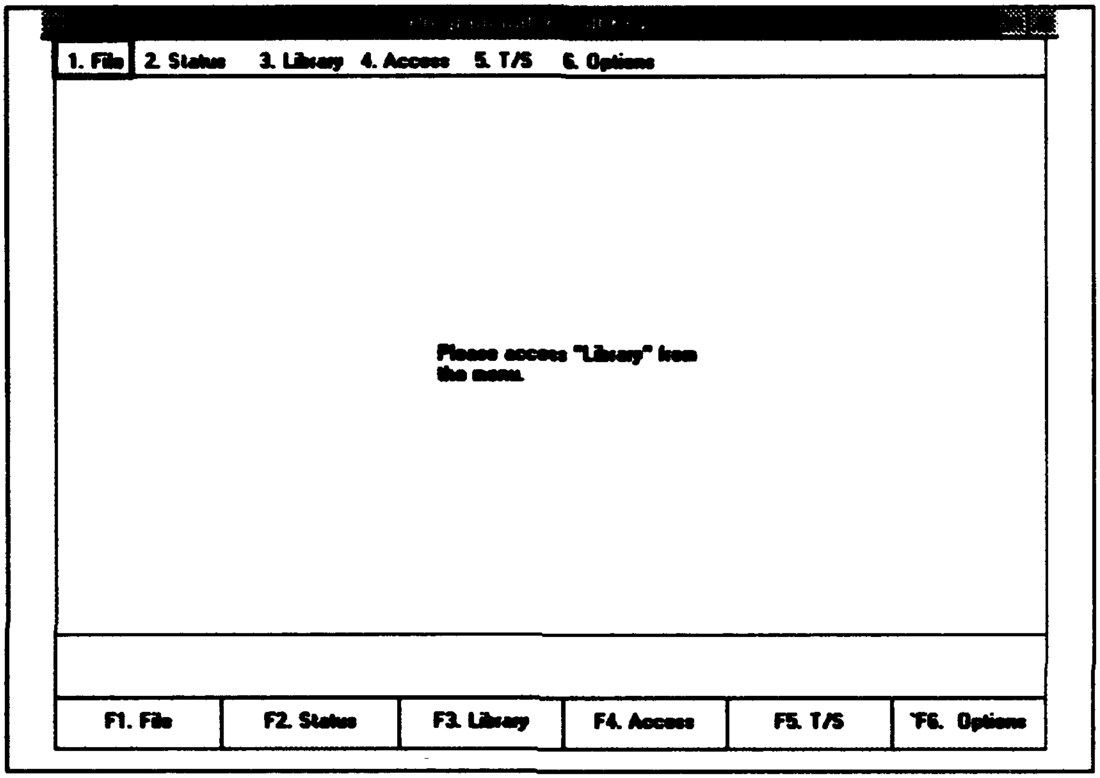
Appendix F: Task 2 Description and Screens

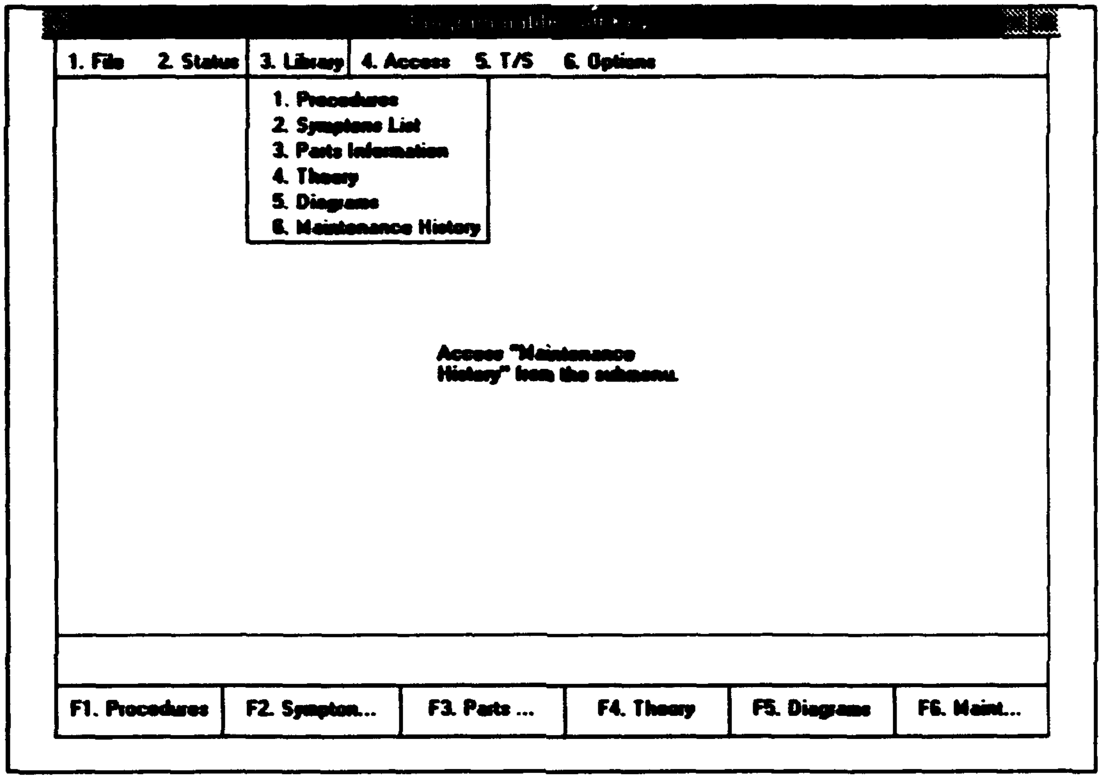


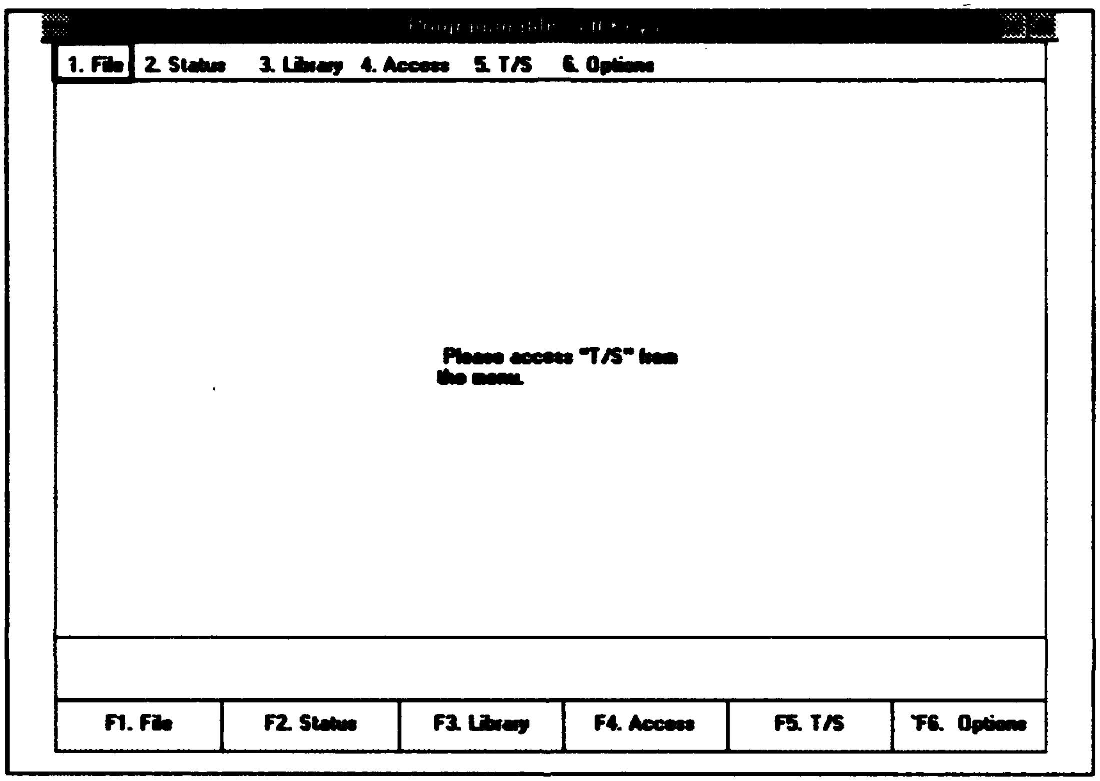

1. File 2. Status 3. Library 4. Access 5. T/S 6. Options
Please Activate the menu.
Use "HOME" key to
activate/deactivate the menu.

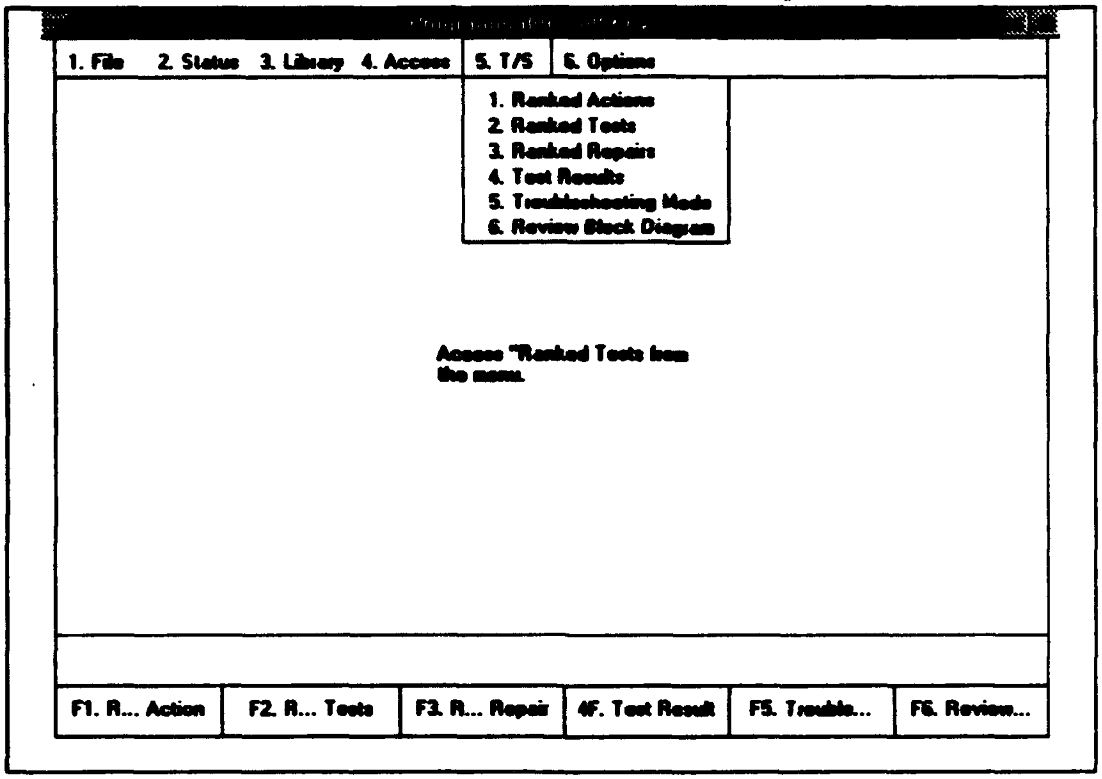

1. File 2. Status 3. Library 4. Access 5. T/S 6. Options
Please access "Status" from the menu.
F1. File
F2. Status
F3. Library
F4. Access
F5. T/S
F6. Options

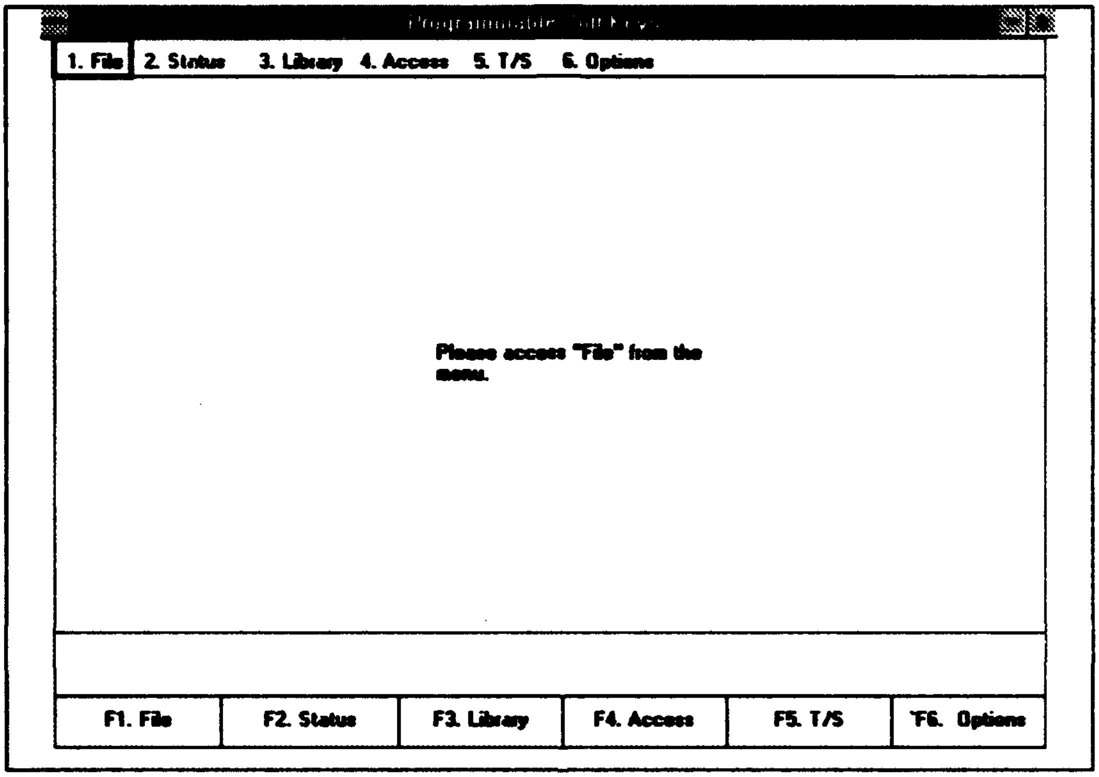

1. File
2. Status
3. Library
4. Access
5. T/S
6. Options
1. A/C Profile
2. Technician Profile
3. Maintenance Profile
4. Form 349
5. Log File
6. Supply Status
Access "Form 349" from the submenu.
F1. A/C Pro...
F2. Tech Pro...
F3. Maint Pro...
F4. Form 349
F5. Log File
F6. Supply ...

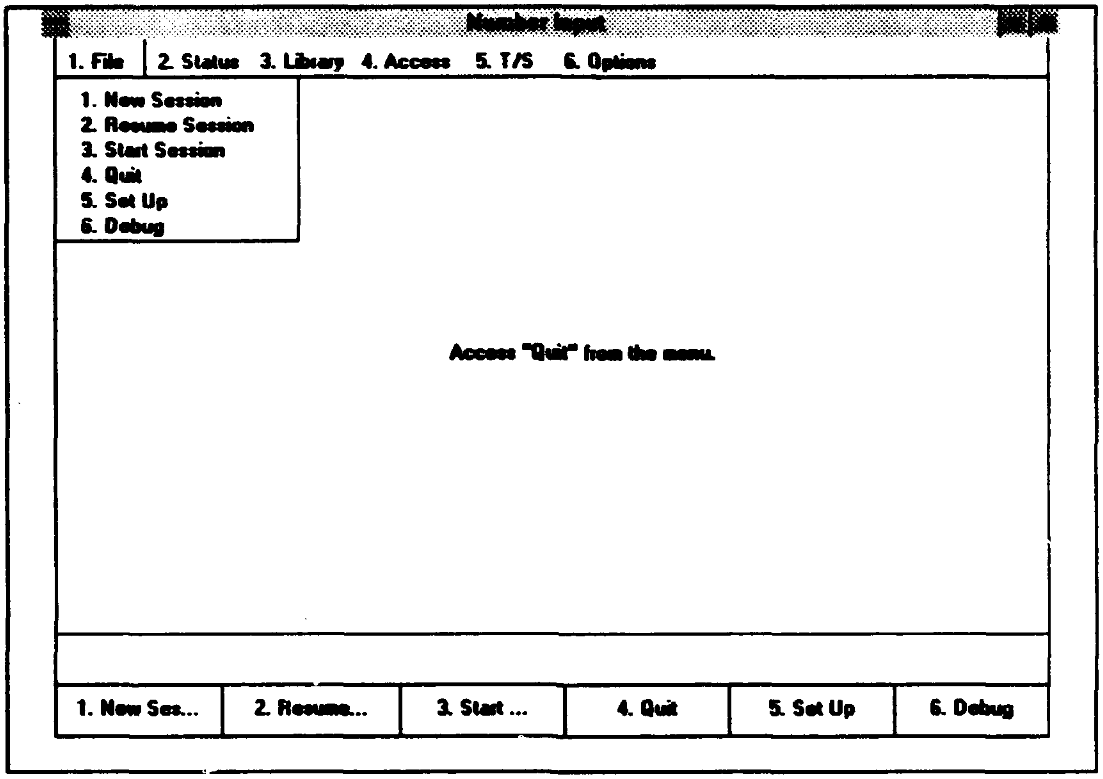

1. File
2. Status
3. Library
4. Access
5. T/S
6. Options
Please access "Library" from the menu.
F1. File
F2. Status
F3. Library
F4. Access
F5. T/S
F6. Options

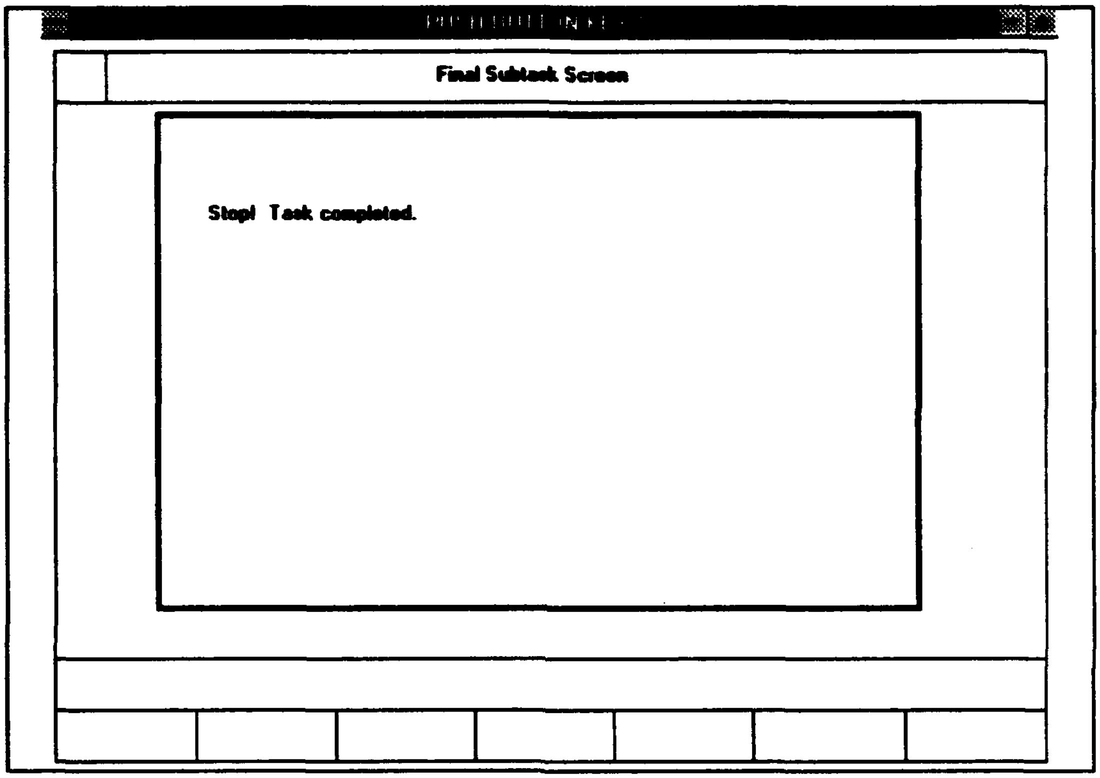

1. File
2. Status
3. Library
4. Access
5. T/S
6. Options
1. Procedures
2. Symptoms List
3. Parts Information
4. Theory
5. Diagrams
6. Maintenance History
Access "Maintenance History" from the submenu.
F1. Procedures
F2. Sympton...
F3. Parts ...
F4. Theory
F5. Diagrams
F6. Maint...


1. File
2. Status
3. Library
4. Access
5. T/S
6. Options
Please access "T/S" from the menu.
F1. File
F2. Status
F3. Library
F4. Access
F5. T/S
F6. Options


1. File
2. Status
3. Library
4. Access
5. T/S
6. Options
1. Ranked Actions
2. Ranked Tests
3. Ranked Repairs
4. Test Results
5. Troubleshooting Mode
6. Review Block Diagram
Access "Ranked Tests from the menu.
F1. R... Action
F2. R... Tests
F3. R... Repair
4F. Test Result
F5. Trouble...
F6. Review...


1. File
2. Status
3. Library
4. Access
5. T/S
6. Options
Please access "File" from the menu.
F1. File
F2. Status
F3. Library
F4. Access
F5. T/S
F6. Options


Number Input
1. File
2. Status
3. Library
4. Access
5. T/S
6. Options
1. New Session
2. Resume Session
3. Start Session
4. Quit
5. Set Up
6. Debug
Access "Quit" from the menu.
1. New Ses...
2. Resume...
3. Start ...
4. Quit
5. Set Up
6. Debug


Final Subtask Screen
Stop! Task completed.

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Vita

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13. ABSTRACT *(Maximum 200 words)*
Portable maintenance aids (PMAs) are being developed to access and store electronic technical information on the flightline. The prototype PMA designed by Armstrong Laboratory personnel has redundant access/navigational features. Redundancy increases software memory usage and adds unnecessary weight to the PMA. The purpose of this research was to determine the best access/navigational feature installed on the PMA. The best feature is the feature that provides the highest degree of user satisfaction. An experiment was conducted to evaluate the following features for screen and menu access and navigation, respectively: dedicated/hardware keys, programmable soft keys, and push button keys; and number keys, cursor control keys, and programmable soft keys. Modified computer screens from the prototype PMA were used on a laptop personal computer, which simulated the PMA, to evaluate each feature one-at-a-time. Twenty-eight maintenance technicians located at Wright-Patterson AFB, OH, rated and ranked each access/navigational feature. The results indicated that the best feature for screen access and navigation was the dedicated/hardware keys and the best feature for menu access and navigation was the number keys.

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